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November 1995

Geoacoustic Study of Delaware Atlantic Coast from Cape Henlopen to Fenwick Island

by Richard G. McGee

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Prepared for U.S. Army Engineer District, Philadelphia

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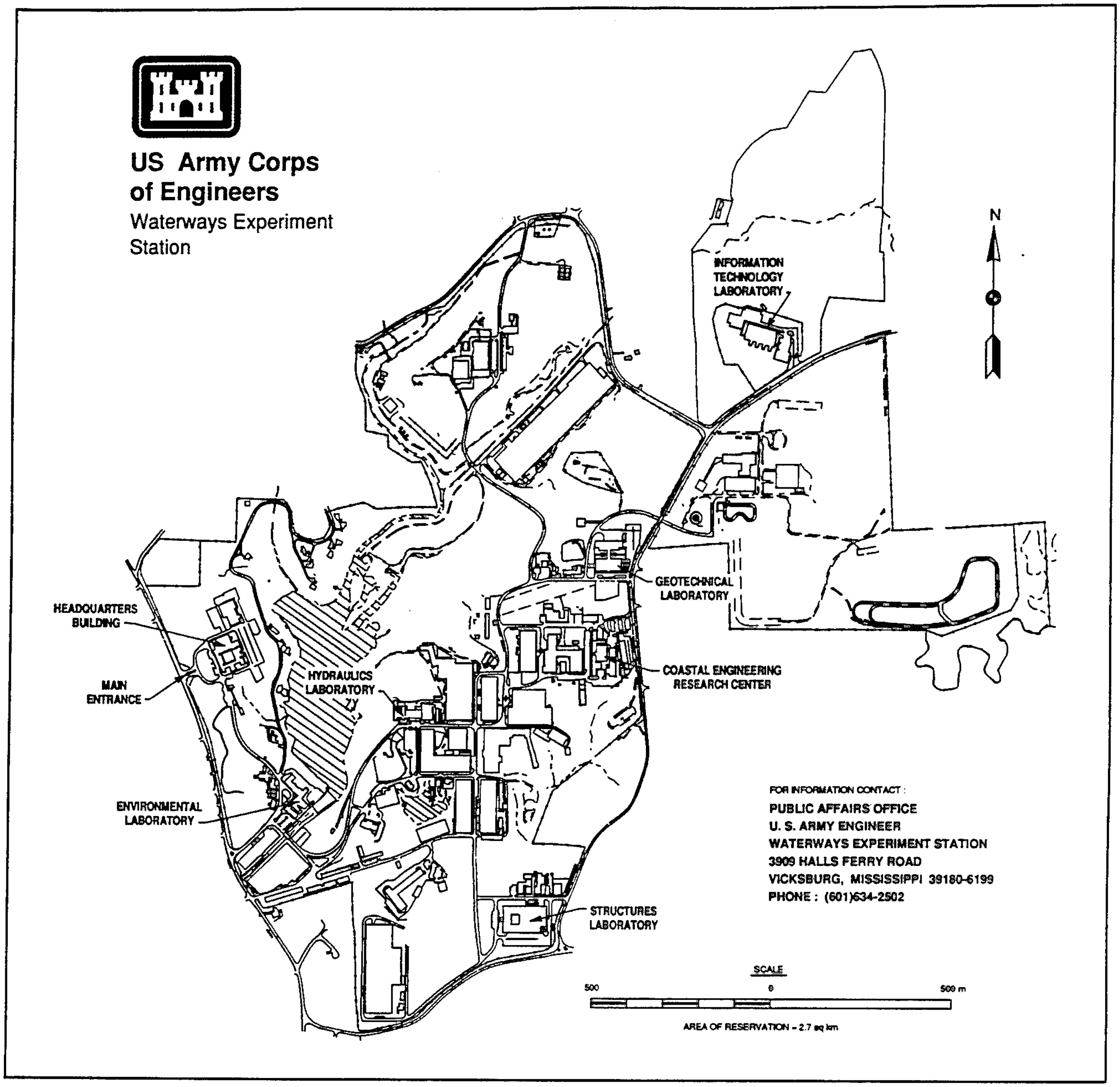

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Preface

A geoacoustic study of the Delaware coast from Cape Henlopen to Fenwick Island was conducted by personnel of the Hydraulics (HL) and Geotechnical Laboratories (GL), U.S. Army Engineer Waterways Experiment Station (WES). The field work was performed during September 1992. The investigation was performed under sponsorship of the U.S. Army Engineer District, Philadelphia (CENAP). The CENAP Project Engineer was Mr. Tony DePasquale.

The overall test program was conducted under the general supervision of Mr. F. A. Herrmann, Jr., Director, HL; Mr. R. A. Sager, Assistant Director, HL; and Mr. G. A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. Mr. Richard G. McGee, Hydraulic Analysis Branch (HAB), HSD, was the Principal Investigator. This project was a cooperative effort with the Geotechnical Laboratory under the supervision of Drs. W. F. Marcuson III, Director, GL, and A. G. Franklin, Chief, Earthquake Engineering and Geophysics Division (EEGD), GL. This report was prepared by Mr. McGee, under the supervision of Dr. B. J. Brown, Chief, HAB. Instrumentation support was provided by Mr. Tom S. Harmon, Jr., EEGD, and by Messrs. David D. Caulfield and David C. Caulfield of Caulfield Engineering, Oyama, BC, Canada. Data analysis assistance during this study was provided by Mr. Rodney L. Leist, EEGD; Ms. Darla C. McVan and Ms. Janie M. Vaughan, HAB; and Mr. Brian Williams, Computer Sciences Corporation, Vicksburg, MS.

Acknowledgment is made to the captain and crew of the Research Vessel *Cape Henlopen*, and administrative personnel of the University of Delaware, College of Marine Studies, for their support in performing the field surveys.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers

1 Introduction

Background

The U.S. Army Engineer District, Philadelphia, is currently preparing a feasibility report for shore protection solutions for the Atlantic coast of Delaware. One specific task in this study is to investigate the offshore marine sediments for potential borrow areas for use as sources of beach-fill materials. Previous investigations in the area off the Delaware coast have been rather limited in scope, either focusing on small, specific study areas, or simply conducted for another objective, such as purely geologic explorations. The Coastal Engineering Research Center (CERC) has conducted investigations north of the project area in the region off Cape May, NJ (Meisburger and Williams 1980), and to the south as part of the Ocean City Hurricane Protection Project (Anders and Hansen 1990). These studies resulted in the identification of sediments for beach renourishment in these regions. However, there are large areas within the vicinity of the Delaware coast yet unexplored. Therefore, as an initial step to the feasibility report investigation, it was decided that a comprehensive subsurface exploration program be initiated for a 3-mile[1]-wide area between Cape Henlopen and Fenwick Island along the Delaware coast (Figure 1) to better establish possible limits of available granular material.

The U.S. Army Engineer Waterways Experiment Station (WES) has developed a high-resolution seismic reflection technique to quantitatively assess the characteristics of bottom and subbottom marine sediments. The technique describes marine sediments in terms of engineering properties, i.e., density, mean grain size, and soil classification, and provides a continuous picture of the horizontal and vertical extent of those properties. The Philadelphia District requested application of this technique in support of the Delaware coast feasibility study.

Overview of Site Geology

The geological evolution of the Delaware continental shelf and Delaware Estuary has been widely studied over the last two decades. Sheridan, Dill, and

[1] A table of factors for converting non-SI units of measurement to SI units is found on page vi.

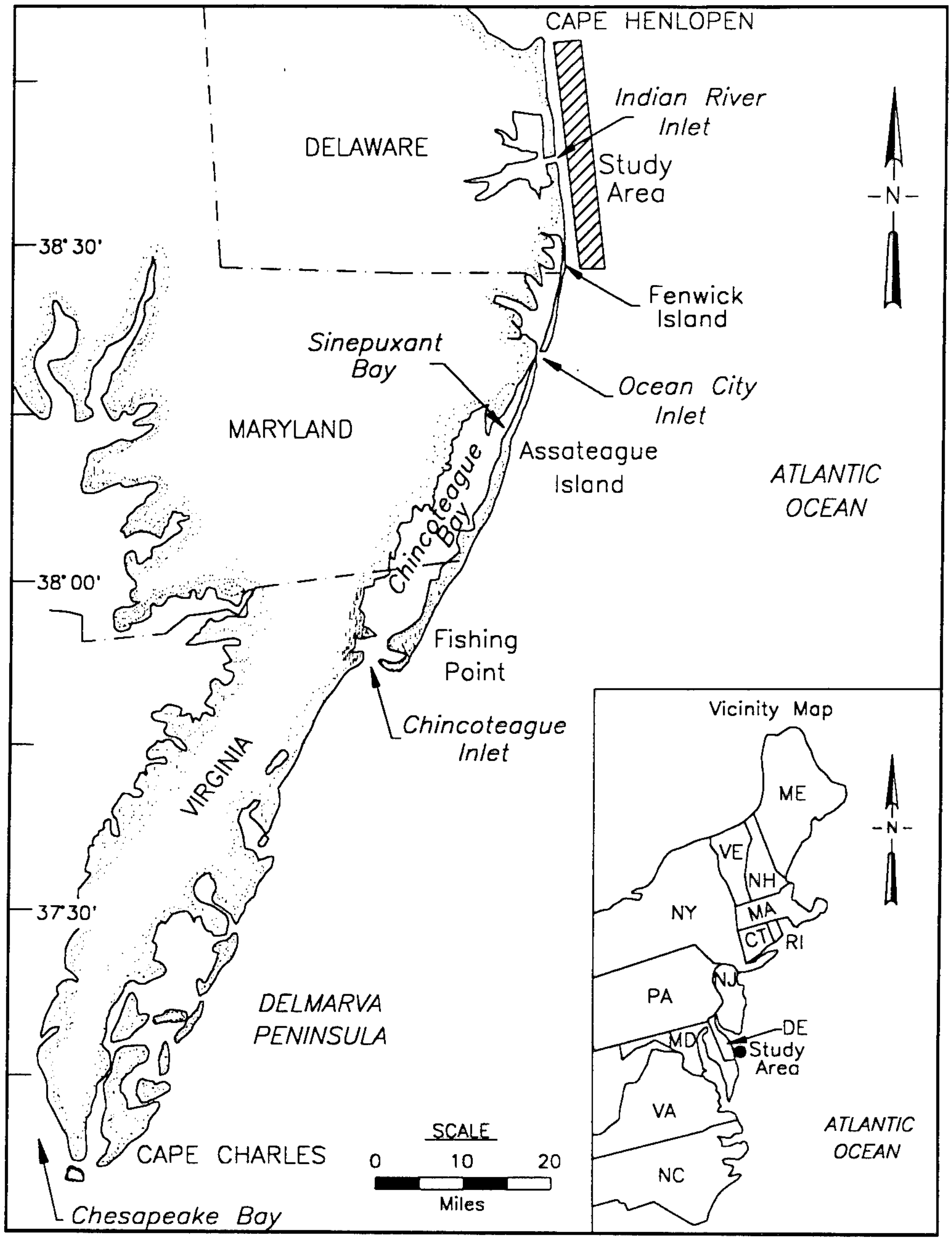


Figure 1. Delaware coast location and vicinity maps

Kraft (1974) provide a thorough discussion of the Holocene depositional environment of the shelf off the Delmarva Peninsula. A summary of the geological evolution by Morang and Pope[1] states that the dominant factor shaping the northeast coast during the Holocene Epoch has been marine

[1] A. Morang and J. Pope. (1993). "Preliminary geomorphic evaluation of potential sand resource areas, offshore of the Delmarva Peninsula," Memorandum For Record, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

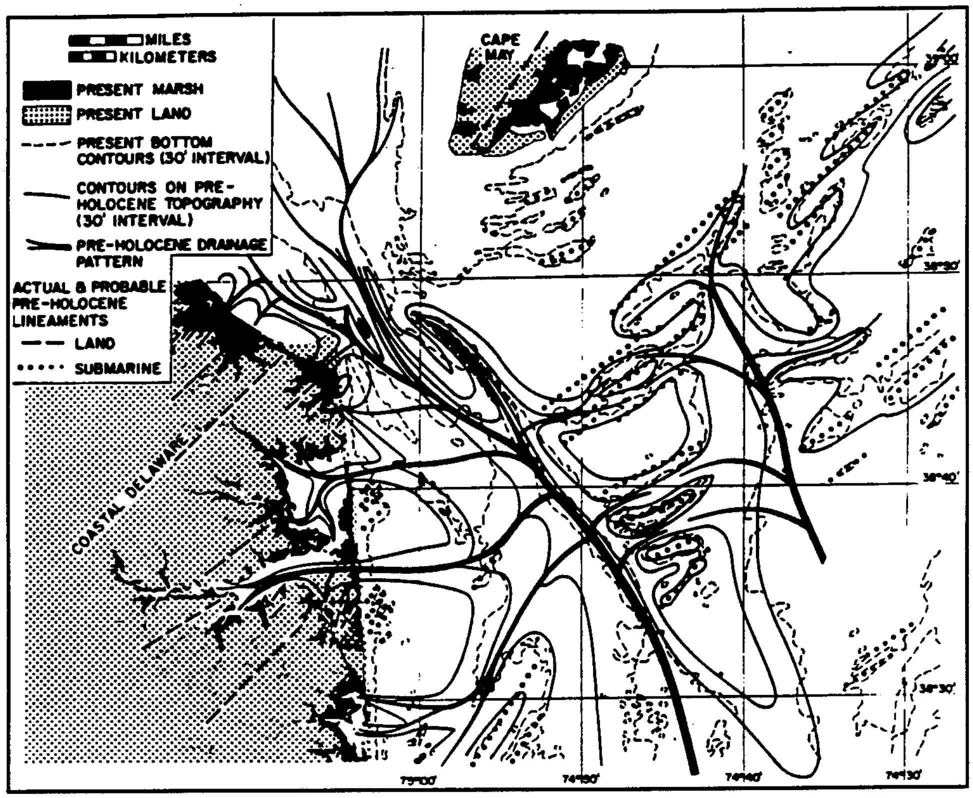


Figure 2. Pre-Holocene topography in the Delaware coastal area (Kraft 1971)

transgression, or the "spread of the sea over land areas." According to Kraft et al. (1979), a deeply incised topography, which included the ancestral Delaware River, and a trellislike drainage system evolved in Delaware's coastal zone (Figure 2). The coastal zone and incised valleys were inundated by the sea as the continental ice sheets melted, releasing enormous volumes of water to the oceans. The rise was accompanied by erosion and shoreline retreat along most of the Delaware coast, resulting in a highly variable coastal morphology of a headland beach with drowned river valley estuaries and remnant beach deposits stranded offshore.

Four major physiographic units have been identified on the shelf off the Delmarva Peninsula (Field 1979): (a) shoreface, (b) linear shoal field, (c) shoal-retreat massif (geologic unit containing one or more summits surrounded by depressions), and (d) shelf transverse valleys. The linear shoals have been interpreted as Holocene features that formed in the submarine environment and were consequently stranded as sea level rose and the shore retreated. They consist primarily of sands and gravels. Valley sediments consist of subsurface deposits of former lagoonal muds overlain by reworked surface sands.

The Holocene sands found in the shoal fields off the Delmarva Peninsula are of primary interest in the search for potential beach-fill sources. In general, these shoals are remnant beach deposits that consist of primarily sands and gravels and are the sediments most likely to be suitable beach fill. Valley sediments surrounding the shoals are typically reworked surface sands containing

significant percentages of fine materials and are generally considered unacceptable as beach fill.

Objective

The objective of this study is to quantify the bottom and subbottom sediments in terms of in situ density, mean grain size, and soil type from the seafloor surface to a depth of about 20 ft below the bottom, where possible, for the study area (Figure 1). The results will (a) provide initial estimates of the sediment characteristics for the purpose of defining the limits of available granular materials and (b) will facilitate the accurate positioning and optimal placement of additional borings by providing nearly continuous coverage of the entire area of interest. The results are not intended to assess the suitability of any marine sediment as beach quality material; rather, the results are intended to pinpoint areas for further detailed investigations.

2 Geophysical Approach

The technique used to quantitatively assess the characteristics of the sediments off the Delaware coast is a modified seismic reflection technique that relates the engineering properties of sediments to acoustic impedance by precisely determining the reflection coefficient at each reflection horizon. This Acoustic Impedance (AI) method is discussed in detail by McGee, Ballard, and Caulfield (1995) and in publications listed in the Bibliography. However, it is necessary to briefly describe the method as it applies to the Delaware coast project. Acoustic theory is discussed only in sufficient detail to enable the reader to understand basic concepts. Specific processing and analysis details will be discussed in Chapter 6, "Phase IV: Geoacoustic Modelling."

Technical Overview

The AI method is an extension of the techniques developed by Caulfield and Yim (1983) and Caulfield, Caulfield, and Yim (1985) for the identification of subbottom marine sediments. The model is an empirical technique that compensates for absorption in each layer as a function of the center frequency of a band-limited seismic trace, corrects for spherical spreading, and uses classical multilayer reflective mathematics to compute reflection coefficients at the sediment horizons. The reflection coefficients are converted to impedances and classified according to established relationships between the acoustic impedance and the geotechnical properties of marine sediments, thereby classifying the lithostratigraphy. Figure 3 illustrates the general processing steps required by the method in practice.

As energy generated from an acoustic source, in the form of a plane wave, arrives at a boundary between two layers of differing material properties, part of the energy will be reflected back toward the surface and part is transmitted as presented in Figure 4. A portion of the transmitted energy will undergo absorption or attenuation in the layer while the remainder propagates through to the next stratigraphic boundary. According to Snell's law and for continuity of stress, the relationship between the incident A_i, reflected A_c, and transmitted A_t waves can be expressed as

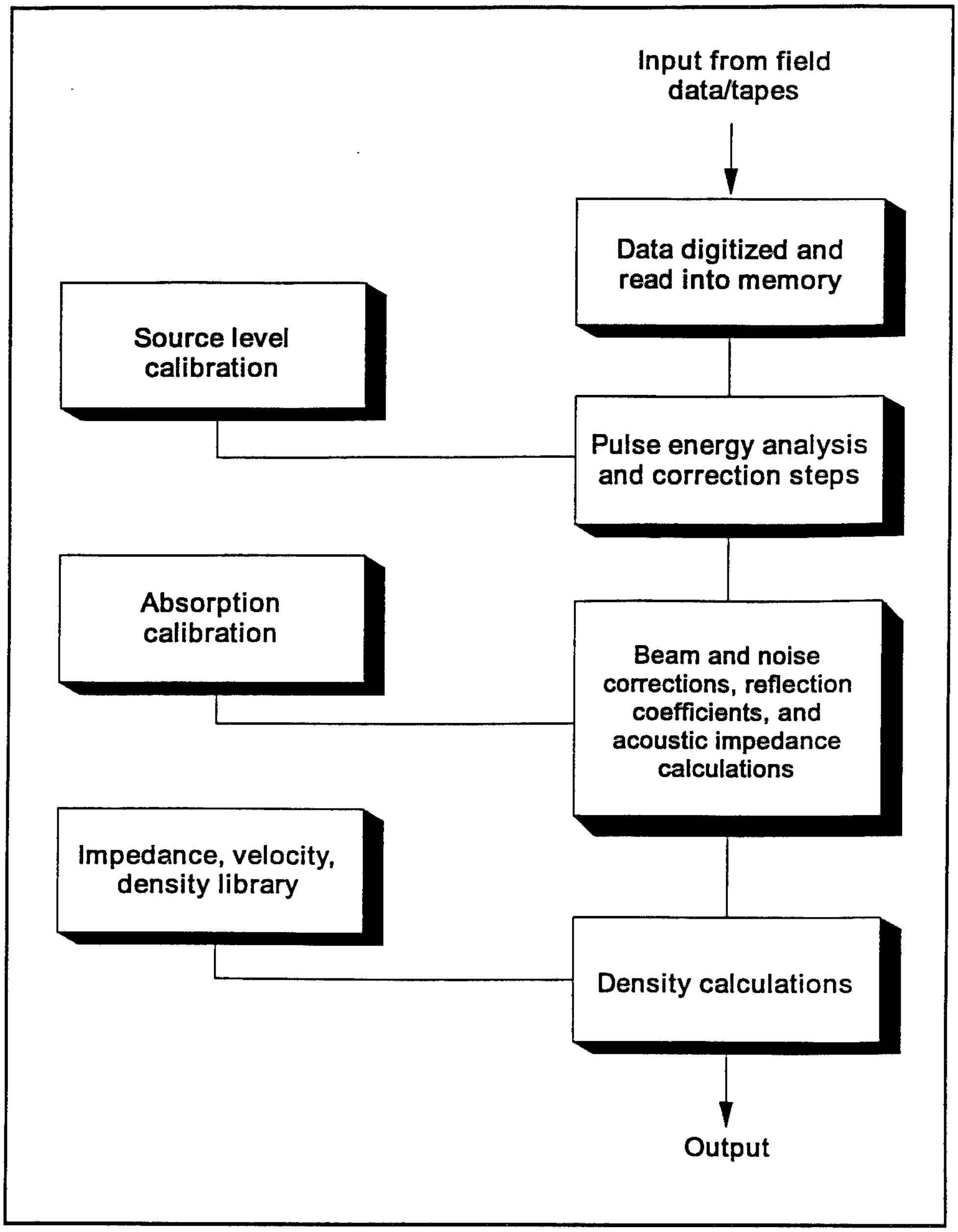


Figure 3. AI processing flowchart

$$A_i - A_c = \left(\frac{E_2/v_2}{E_1/v_1} \right) A_t \qquad (1)$$

where E_1 and E_2 are the elastic moduli of media 1 and 2, respectively, and v_1 and v_2 are the velocities in each. For a perfectly elastic medium $E = \rho v^2$, where ρ is the mass density and v the elastic P-wave velocity. The quantity ρv is called the *acoustic impedance*, Z, of the medium and thus represents the influence of the medium's characteristics on the reflected and transmitted

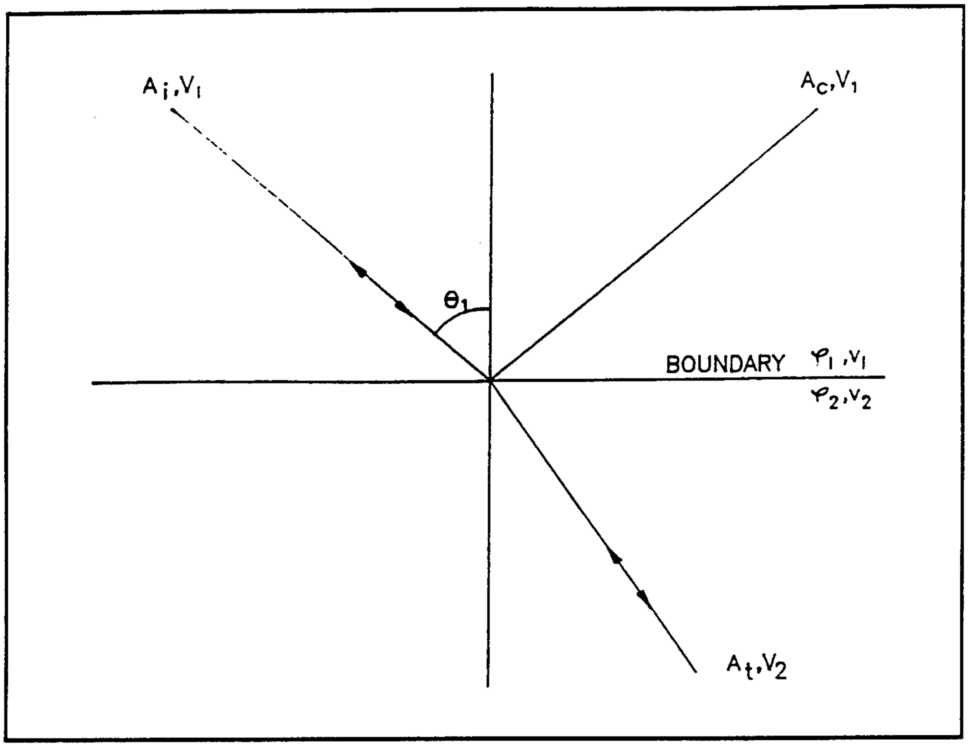


Figure 4. Acoustic wave propagation at a boundary between two interfaces; Snell's law

waves. The reflection coefficient R is defined as the percentage of the wave's reflected energy. The acoustic impedance and the reflection coefficient are related through the Zoeppritz equation as

$$Z_2 = Z_1 \left(\frac{1 + R}{1 - R} \right) \tag{2}$$

where Z_1 and Z_2 are the impedances of the first and second mediums, respectively. This relationship provides a straightforward method for determining acoustic impedance. By knowing the first Z and the succeeding R's, one can then calculate all the acoustic impedances. In this case, the first layer is always seawater, which has a known typical impedance value of 1,550 10^2 g/cm^2 sec. By calculating the remaining R's, the problem is solved.

The relationship between acoustic impedance and specific soil properties has been empirically derived from world averages of measured impedance versus sediment characteristics (Hamilton 1970a,b; 1972a,b; Hamilton and Bachman 1982). Further development of statistical models and algorithms (Caulfield and Yim 1983) establishes relationships between acoustic impedance and soil properties (porosity, bulk density, mean grain size, etc.) for sediments within various natural marine environments and allows the identification and characterization of the subbottom layers from acoustically derived seismic reflection data.

Processing of the seismic data involves determining the precise reflection coefficient at each detectable reflection horizon. This requires that the major losses associated with acoustic wave propagation in a layered sediment environment be properly accounted. These losses include (a) transmission loss due to spherical spreading, (b) transmission through reflectors, and (c) intrinsic absorption within a particular sediment unit. Each of these losses is assessed using processing and analysis tools developed specifically for the AI method. These tools include the Acoustic Core System (Caulfield 1992), the Digital Spectral Analysis System (Caulfield 1991b), the Digital Shallow Seismic Processing and Correlation System (Caulfield 1991a), and in-house WES programs for equipment calibrations and bottom surface analysis using the sonar equations. These programs will be discussed in more detail as they were employed in the Delaware coast study.

Seismic reflection signatures are not universally unique; i.e., several combinations of geologic conditions could conceivably yield similar signal characteristics resulting in similar impedance values. But in a given geologic setting, such as the Delaware coast and shelf, a particular sediment usually has a characteristic, relatively narrow range of impedance values. Therefore, project-specific calibrations are used to relate specific acoustic signatures to respective reflectors. Using calibration procedures incorporating local core data, the acoustic reflection data are processed to yield accurate acoustic impedance values at reflection horizons for the geologic region of interest. The geoacoustic calibrations for the Delaware coast project are discussed in Chapter 6.

Delaware Coast Study Outline

The Delaware coast study was divided into five primary phases as shown in Figure 5 and listed as follows:

a. Phase I: Seismic data acquisition

b. Phase II: Data processing and mapping.

c. Phase III: Physical sediment analysis.

d. Phase IV: Geoacoustic modelling.

e. Phase V: Sediment profiles and description (discussion of results).

Phase I included all project planning, geologic overviews, survey planning, and field activities required to collect the data necessary to meet the study objectives. The initial data processing performed in Phase II involved integrating all data, particularly the seismic with the navigation data, and generation of all survey- and tide-corrected bathymetric maps, including contours and depth profile plots. The digital seismic data playback was performed on all data collected, providing color hardcopy records of the raw

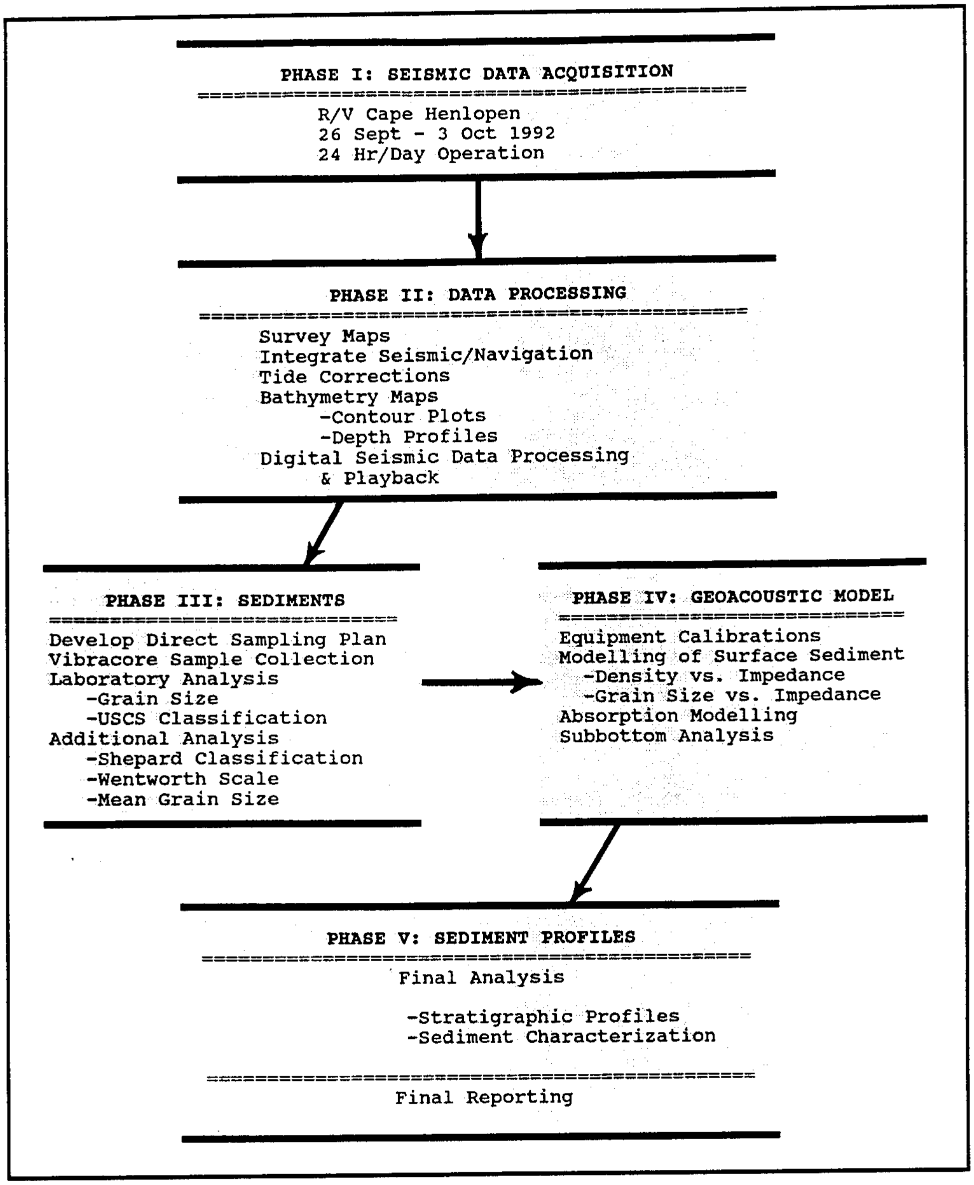


Figure 5. Delaware coast study outline

acoustic data. This process also involved processing of the raw data to improve the signal-to-noise (S/N) ratio of the data, where possible, and to enhance the detection of deeper reflection horizons.

Physical sediment collection analysis (Phase III) involved developing a direct sampling plan to describe the various sediment layers based on the acoustic reflection data. Vibracore samples were collected and subsequent laboratory analysis performed to provide the engineering properties of the sediments. Phase IV was the geoacoustic modelling stage of the study. All final equipment calibrations, surface sediment modelling, absorption modelling, and final subbottom analysis were performed here. The geoacoustic solution was developed into stratigraphic profiles characterizing the sediment properties through the geoacoustic relationships developed for this study.

Finally, sites characterized as primarily sand were selected for further testing by the Philadelphia District. The remainder of this report is organized according to this process flowchart and describes each phase in detail.

3 Phase I: Seismic Data Acquisition

Survey

The Delaware coast survey encompassed basically a 3-mile-wide area along the entire length of the Delaware Atlantic coast, a distance of approximately 24 miles (Figure 1). Due to the large area involved, the survey was divided at approximately the midpoint into northern and southern areas. The division occurred at the southern end of Rehoboth Bay, just north of the Indian River Inlet. Eleven survey lines offset at 500-m intervals running parallel to the shore were surveyed in both northern and southern sectors. Line 1, closest to shore, was approximately one-half mile offshore, with each line originally scheduled for 12-mile-long segments. Figure 6 presents the actual survey lines for the entire project. Each survey line is numbered sequentially within each sector from line 1 to 11, increasing away from shore. The northern sector line numbers are denoted with an *N* suffix and the southern sector lines accordingly with an *S*. All coordinates are presented in Delaware State Plane, NAD 83. (Note: Survey lines 7N and 8N are swapped as shown in Figure 6. The seventh line from shore is line 8N and the eighth line from shore is 7N.)

For the most part, the survey lines were run exactly as proposed. Around the Hen and Chickens Shoal in the northern sector of the study area, portions of some lines had to either be rerouted or eliminated altogether due to shallow water. Specifically, the northern one-third of line 1N was eliminated as well as portions of lines 2N and 3N. Also, line 4N in the vicinity of the shoal was rerouted to avoid shallow water. In the southern sector, only the most northerly segment of line 1S deviated from the proposed survey, in the vicinity of Indian River Inlet, due to shallow waters of the ebb shoal. In all, nearly 250 line miles were surveyed, requiring almost 6 days to complete with a 24-hour per day work schedule.

Equipment

Survey vessel

The survey was conducted aboard the Research Vessel *Cape Henlopen*

operated by the University of Delaware, College of Marine Studies, Lewes, DE. Figure 7 presents the general arrangement of the main deck. Locations of the geophysical equipment and fathometer are shown. Details regarding each piece of equipment are discussed in the following sections. The recording area was located in the dry laboratory on the port side of the main deck.

Navigation and bathymetry

The navigation and high-frequency bathymetry information for the survey was provided by Gahagan & Bryant Associates. A differential global positioning system (DGPS) was employed for horizontal positioning. The DGPS equipment consisted of the following:

a. Trimble Navigation 4000 RL II, the DGPS reference station.

b. Trimble Navigation 4000 DL II, the mobile global positioning system receiver.

c. Dataradio Radio/Modem Link, the differential correction data link.

The equipment is rated at providing horizontal accuracy of ±1 to 3 m root mean square (RMS) (68 percent of the time). DGPS was used for horizontal positioning only.

Bathymetry was provided by the Krupp Atlas Deso 20 fathometer. A single high-frequency transducer, 210 kHz, was used for sounding. The fathometer, located off the port side as shown in Figure 7, was calibrated at the start of the project by the standard bar check method. Tide data were obtained by the Philadelphia District from the National Oceanic and Atmospheric Administration (NOAA) tide gage number 8557382 at Lewes, DE, and postprocessed with the fathometer data to arrive at depth elevations referenced to mean lower low water.[1]

The navigation and bathymetric equipment was interfaced with a Hewlett Packard 310 computer to record and provide real-time navigation information. Additional interfacing included a serial connection for the output of position coordinates and high-frequency bathymetric data directly to the digital seismic data acquisition system.

Geophysical equipment

The acoustic subbottom reflection records were generated using a 3.5- to 7.0-kHz high-resolution "pinger" system and an integrated, high-definition

[1] Elevations and depths cited in this report are in feet referenced to mean lower low water (mllw).

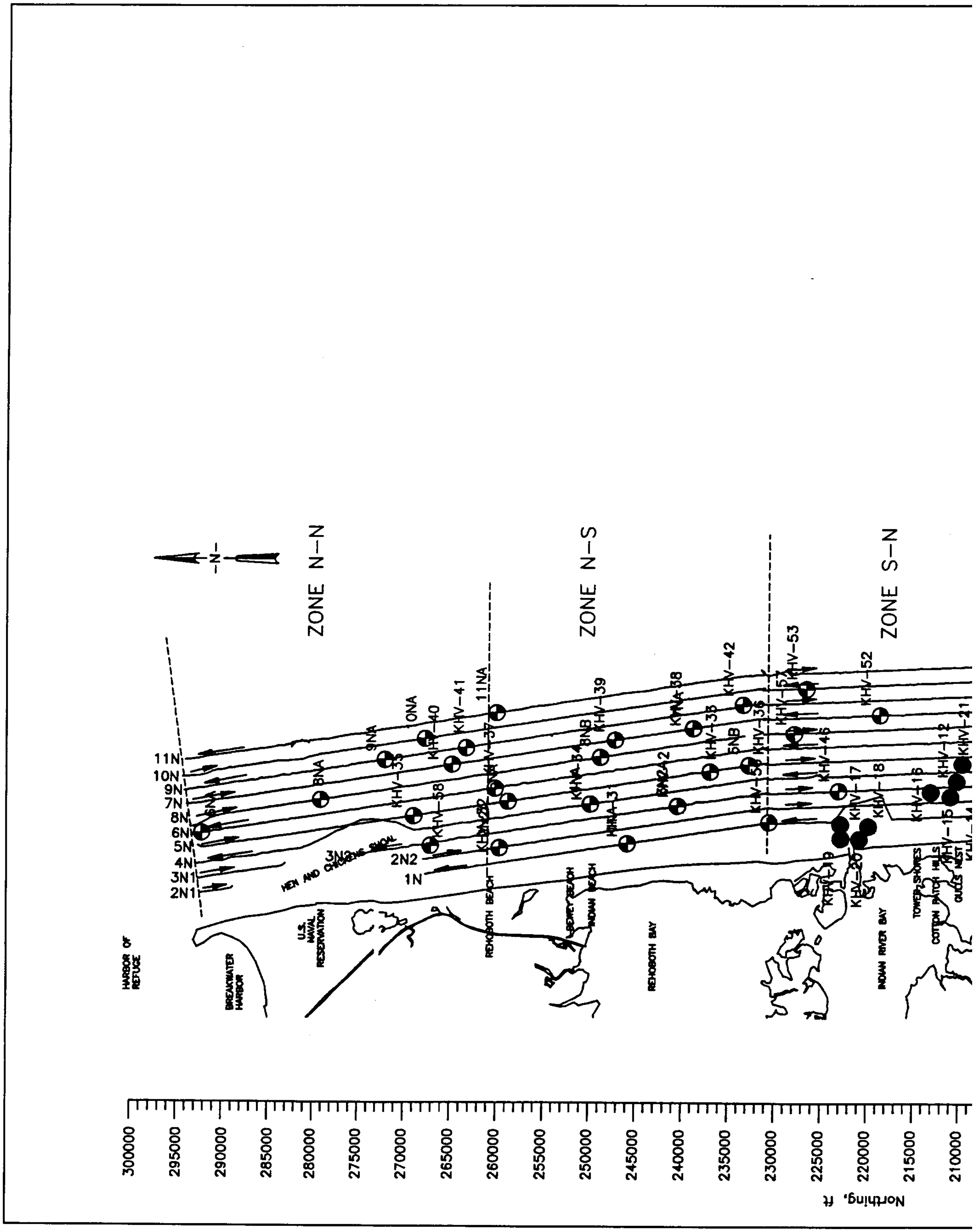
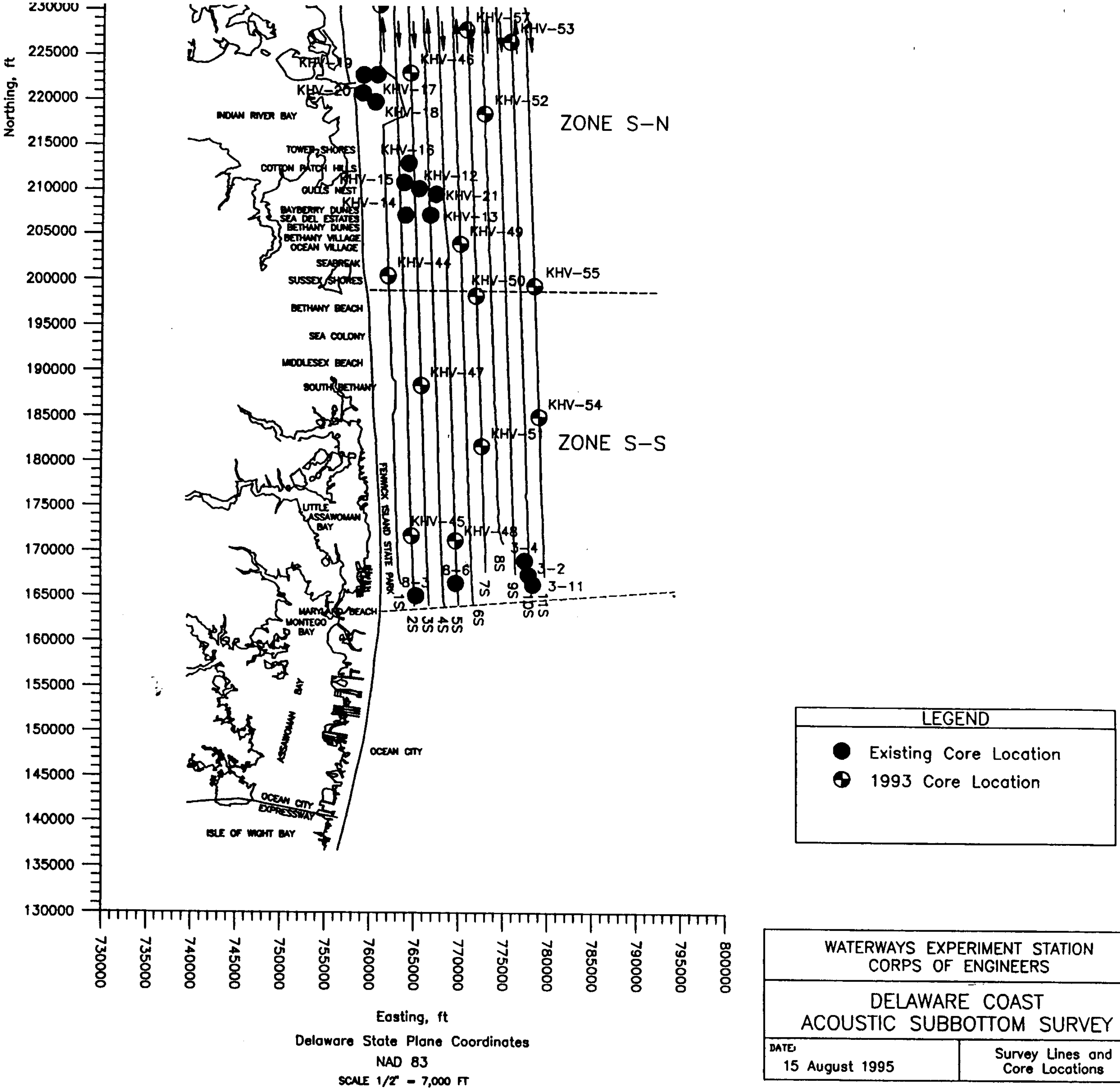


Figure 6. Survey lines and core locations



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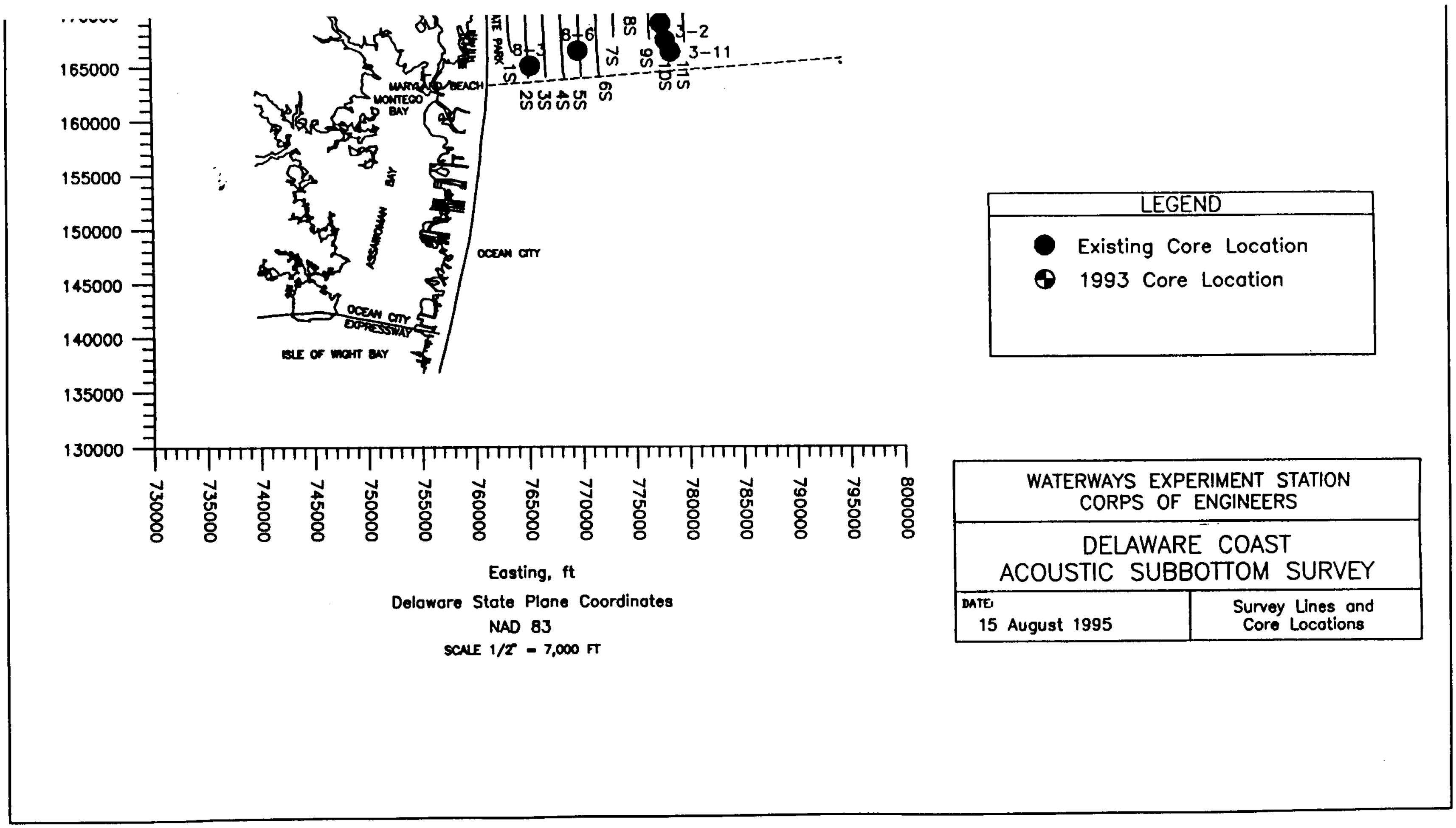
CORPS OF ENGINEERS

DELAWARE COAST
ACOUSTIC SUBBOTTOM SURVEY

DATE: 15 August 1995	Survey Lines and Core Locations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800000
Easting, ft
Delaware State Plane Coordinates
NAD 83
SCALE 1/2" = 7,000 FT
MARYLAND BEACH
MONTEGO BAY
ASSAWOMAN BAY
OCEAN CITY
OCEAN CITY EXPRESSWAY
ISLE OF WIGHT BAY
1S
2S
3S
4S
5S
6S
7S
8S
9S
10S
11S
8-3
8-6
3-2
3-11
LEGEND
Existing Core Location
1993 Core Location
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Survey Lines and
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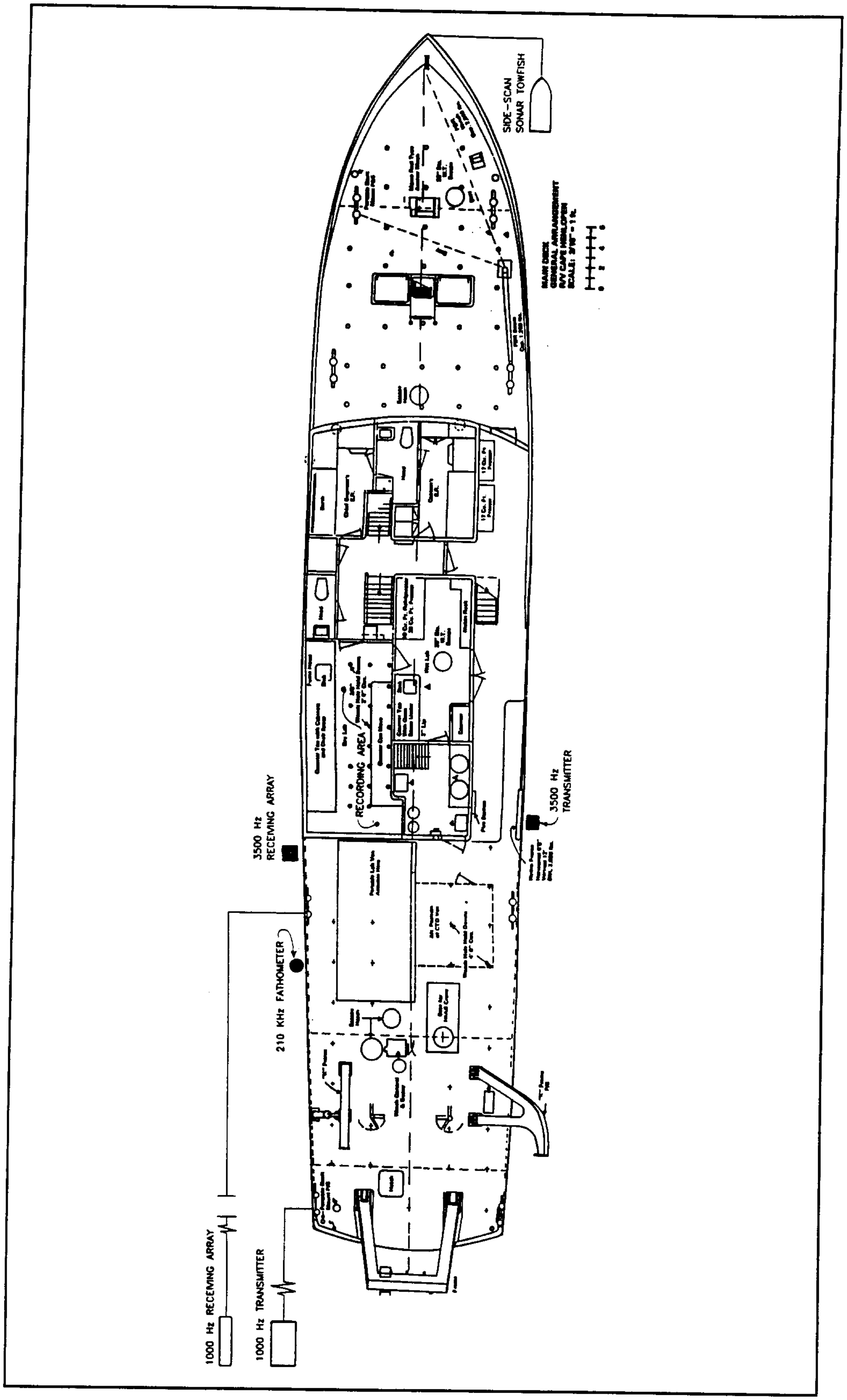


Figure 7. Survey vessel and instrumentation arrangement. Only components pertaining to this study are labelled

400-Hz to 5.0-kHz "boomer" system. The specific systems used were as follows.

3.5- to 7.0-kHz pinger system. This system allows the transmission of variable-length acoustic pulses (0.2 - 3 msec) of 3.5- and 7.0-kHz frequencies. Power levels can be varied from 1 to 10 kW. However, depth of penetration can be limited in areas of highly competent sediments. For the Delaware coast survey, the following operating parameters were chosen:

a. Power setting: 5 kW

b. Frequency: 3.5 kHz

c. Pulse length: 1 msec

d. Ping rate: 0.25 sec

The relatively long 1-msec pulse length was chosen in the field during mobilization due to the sea state conditions and the fact that the survey was basically being conducted with waves and swell approaching the vessel broadside. This resulted in significant boat roll, and the longer pulse length provided much improved S/N data over the higher resolution, shorter pulse lengths normally employed.

These systems were originally designed to operate in water depths greater than about 50 ft, resulting in configurations employing integrated transmit/receive (T/R) networks in order to use the same transducers as transmitters as well as receivers. The resulting transducer ringing and coupling create coherent noise keyed to the transmitter timing. In shallow water, less than 30 ft, significant S/N problems arise due to the coherent noise from the transmitter interfering with the first return.

To solve this problem, a receiving array was deployed independently of the transmitter as shown in Figure 7. By decoupling the receiving array from the transmitter and physically separating the transducer, all of the near-field transmitter ringing was eliminated from the bottom reflection, regardless of water depth. This is the standard pinger deployment configuration for the AI method.

Boomer system. This system is a high-energy, medium-bandwidth unit providing up to 1,000 joules of energy in the 400- to 5,000-Hz frequency band. The system is designed to provide reasonable vertical resolution combined with greater penetration depths in more competent sediments. Due to the primarily marine sand environment off the Delmarva Peninsula, a seismic system capable of detecting deeper sediment interfaces below the ocean bottom sands than the higher frequency pinger system could detect was required for verification of sediment thicknesses.

Because of the high power involved and because the coherent noise radiates to the receiver as well as to the bottom, an array is towed separately. This

array is normally towed at right angles or directly aft of the source. The exact tow point is determined by the water depth and by where the coherent noise to the receiver is minimized. Figure 7 presents the boomer configuration used for the Delaware Coast survey. The boomer source and receiving array were towed approximately 100 ft aft of the vessel. The receiving array was horizontally offset from the source by approximately 30 ft as shown in Figure 7. The reflected signals from the boomer array were band-pass filtered between 400 Hz and 2,200 Hz at a center frequency of near 1,000 Hz.

Side-scan sonar. A dual-frequency side-scan sonar (SSS) was operated throughout the survey to provide increased areal bottom coverage. The SSS was operated at 100 kHz and was towed off the bow as shown in Figure 7. Although not specifically presented within this report, the SSS data were used to identify unique bed forms such as sand waves and were used primarily in preparing the direct sampling plan. The SSS digital data files and analog records are archived at WES.

4 Phase II: Data Processing and Mapping

Acoustic Reflection Data Records

Continuous subbottom profiles of the acoustic reflection amplitudes obtained using the 3.5-kHz pinger system and the boomer system for surveys performed offshore of the Delaware coast were delivered to the Philadelphia District Project Engineer. The digital data are archived at WES. The records are annotated with digital file numbers, relative depth scales, and all core locations. Figure 8 is a typical color subbottom amplitude record from the Delaware coast survey. The color code represents relative reflection amplitudes as displayed by the legend on the figure. The vertical lines along the top portion of the record are the beginning of individual digital data files, recorded continuously during the survey. Files are sorted into six subfiles (0-5) with each subfile containing bins of forty consecutive soundings. These file numbers are used on the final sediment profiles to correlate the calculations with the raw data. Note the top of the graph is not necessarily the water surface, but an assigned water column offset. This offset allows full vertical expansion of the subbottom display, which in this case extends into the subbottom more than 50 ft. Changes in stratigraphy are readily apparent and are represented as subbottom reflectors generated by impedance mismatches at the sediment interfaces (refer to Equations 1 and 2). Also labelled in Figure 8 is a multiple reflection generated as the first bottom echo alternately reflects between the water/seafloor and air/water interfaces. As the name implies, multiple reflections track the bottom in multiples of the water depth, thus limiting the effective depth of acoustic penetration by possibly masking actual sediment interfaces. No multiple suppression techniques have been developed for the AI method, therefore limiting quantitative acoustic assessment to the multiple depth.

Bathymetry

The acoustic reflection data were combined with the position data and the high-frequency bathymetric data, providing accurate determination of both the horizontal and vertical datums. Bottom depths for the subbottom profiles were adjusted to the tide-corrected fathometer depth measurements since the data

provide nearly a 10:1 improvement in resolution over any of the subbottom equipment. A contour map of the measured topography is presented in Figure 9.

The survey line spacing of approximately 500 m precluded a detailed evaluation of the bottom topography of the area; however, major physiographic features are quite evident. In the northernmost section of the survey, identified as Zone N-N in Figure 9, drastic changes in bottom elevation occur proceeding northward across the Hen and Chickens Shoal. Measured water depths along the crest of the Hen and Chickens Shoal are shallower than -30 ft with depths plunging to greater than -90 ft to the north in the vicinity of the main entrance channel of the Delaware Bay. The shoal connects the shoreline just south of Cape Henlopen near Lewes, DE, and extends in a southeasterly direction as far south as Rehoboth Beach. South of the Hen and Chickens Shoal directly east of Rehoboth Bay is depicted what has been identified as a shelf-transverse valley. Bottom elevations become deeper proceeding away from shore with nearshore elevations at -35 ft gently sloping to near -65 ft along the eastern edge of the study area. Except for linear shoals located between Dewey Beach and Indian River Inlet and nearshore shoal fields just north of Bethany Beach with shoal crest elevations as high as -25 ft, the bottom topography remains relatively flat, particularly in the eastern portion of the survey area, between Dewey Beach and Bethany Beach. The bathymetric data near the southernmost end of the study area along Fenwick Island show a large and relatively complex shoal field situated primarily in the eastern half of survey Zone S-S. Average shoal crest elevations in this area are -35 ft with the surrounding seafloor at approximately -45 ft.

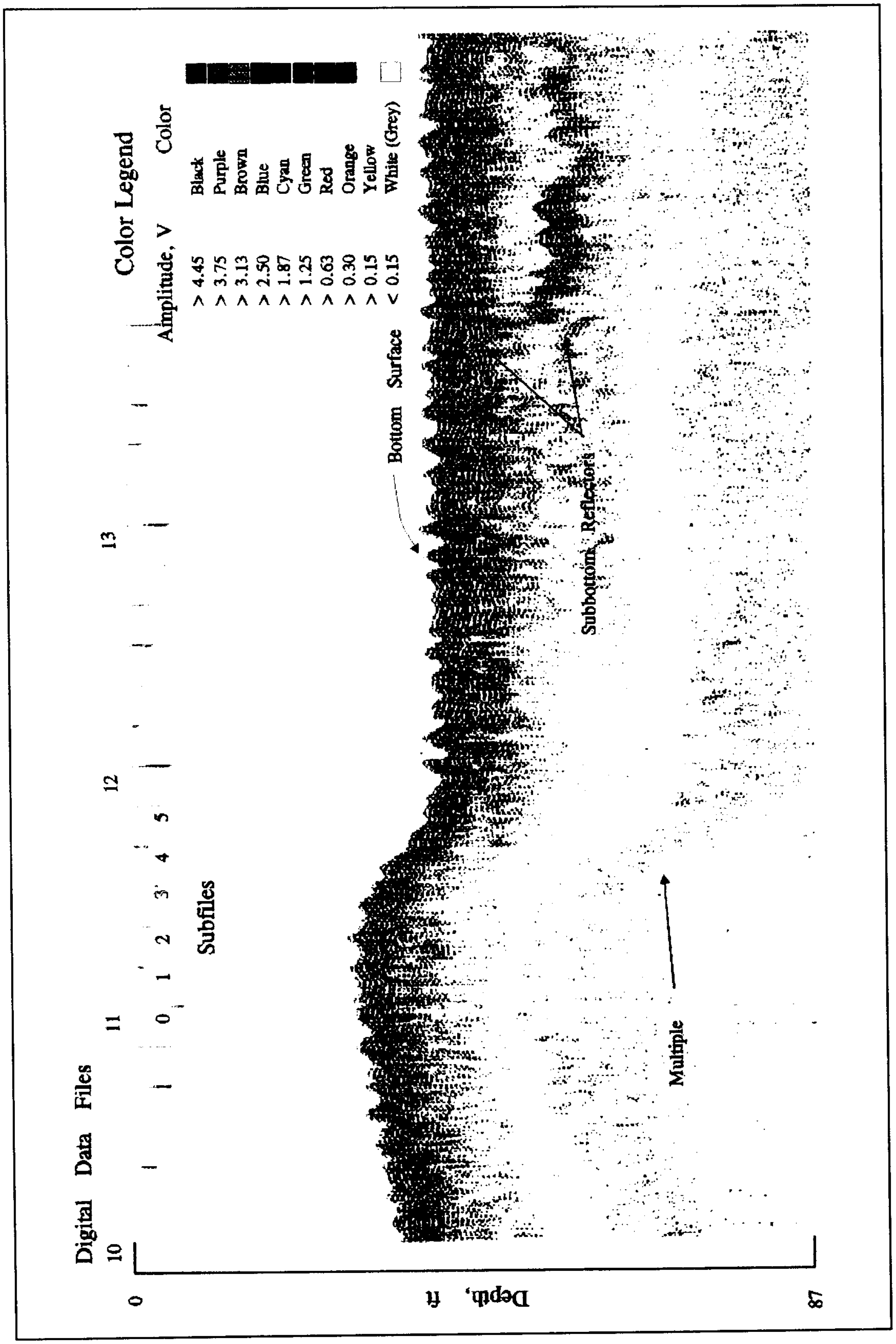


Figure 8. Typical color subbottom amplitude record

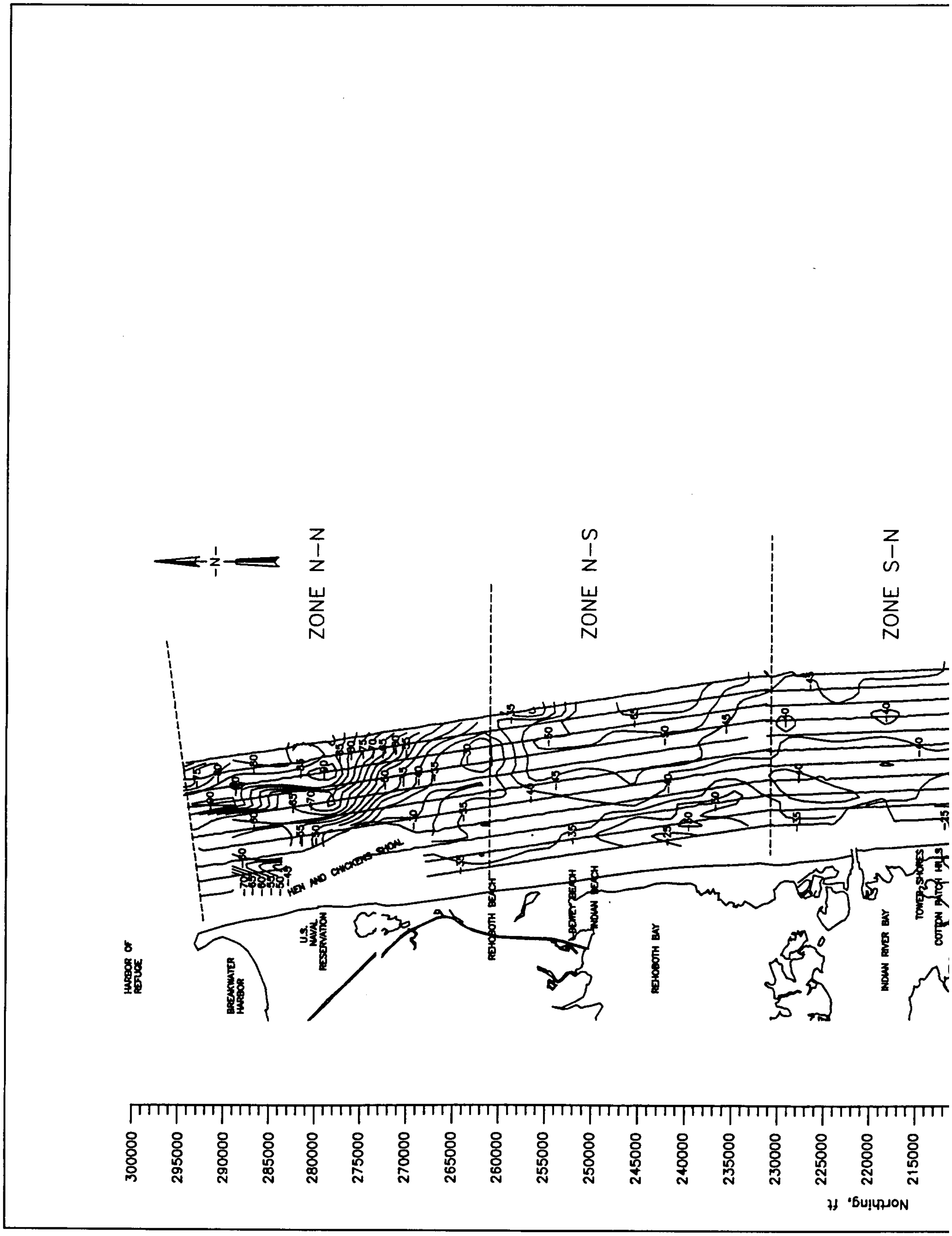
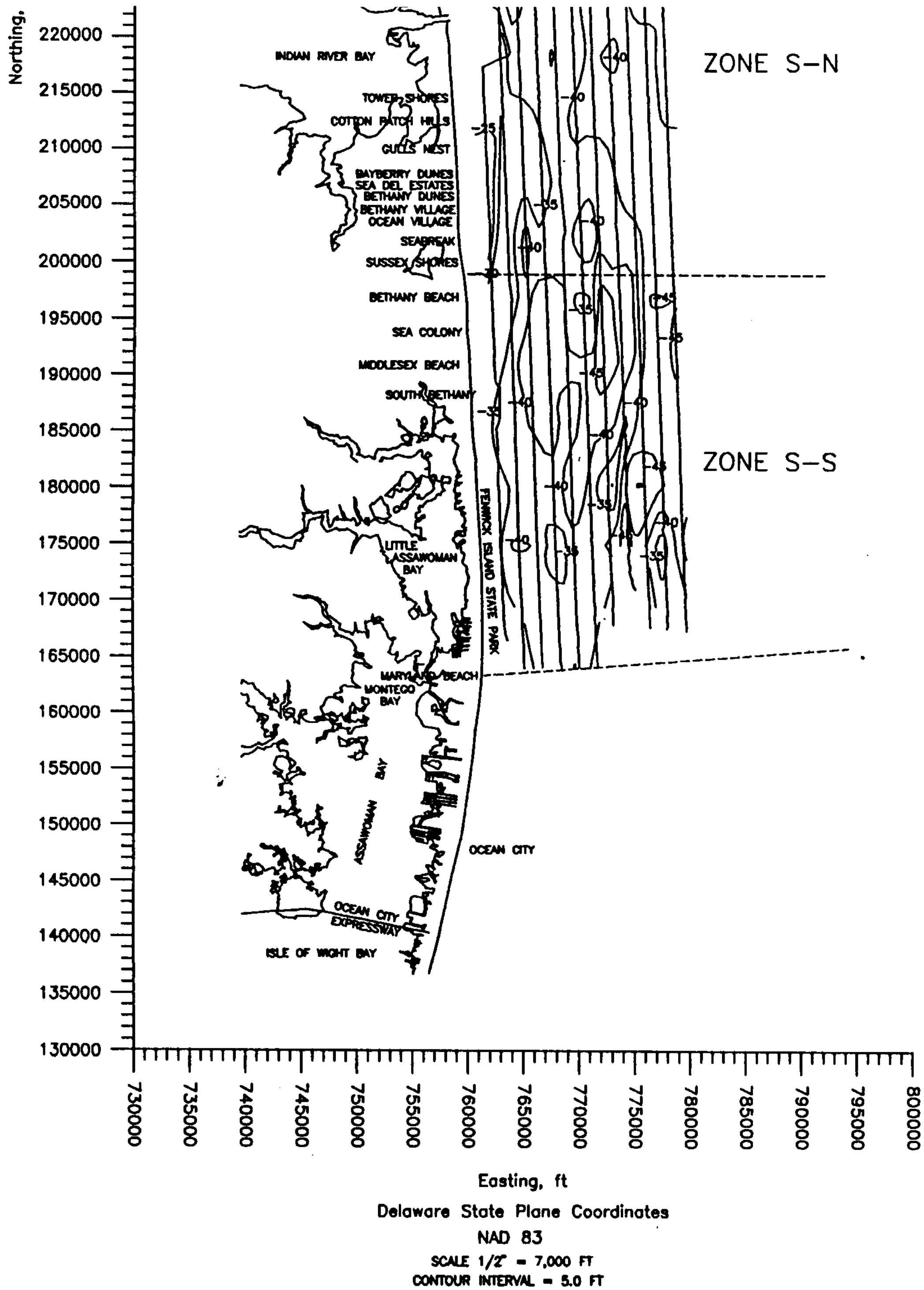
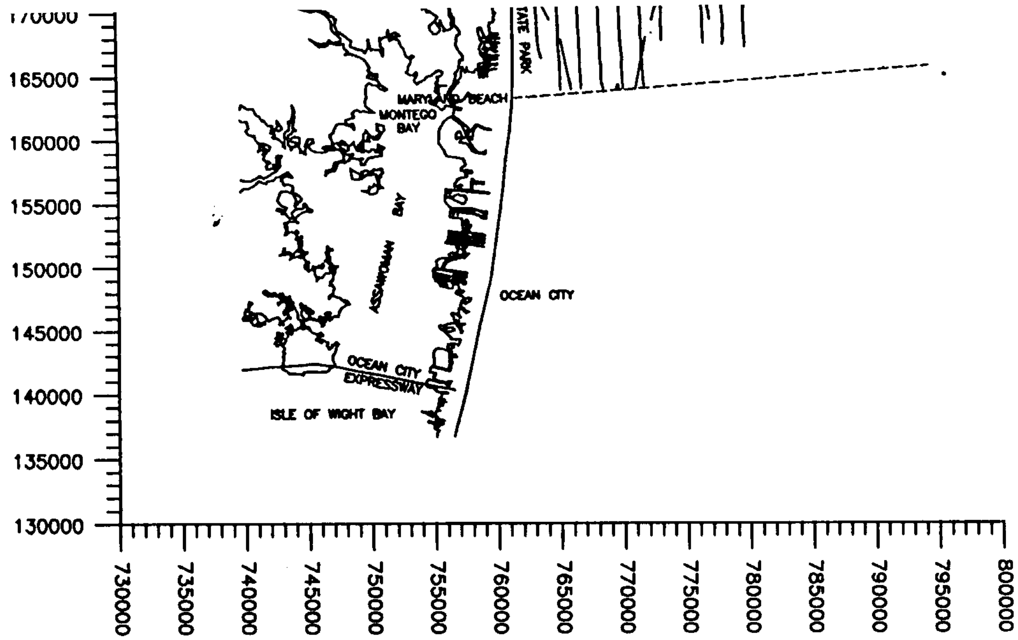


Figure 9. Contour map of Delaware coast bathymetry



WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS	
DELAWARE COAST ACOUSTIC SUBBOTTOM SURVEY	
DATE: 15 August 1995	Survey Lines and Core Locations

Note: Contours are given in feet referred to mllw.



Easting, ft

Delaware State Plane Coordinates

NAD 83

SCALE 1/2" = 7,000 FT

CONTOUR INTERVAL = 5.0 FT

WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS	
DELAWARE COAST ACOUSTIC SUBBOTTOM SURVEY	
DATE: 15 August 1995	Survey Lines and Core Locations

Note: Contours are given in feet referred to mllw.

5 Phase III: Physical Sediment Analysis

Core data required to calibrate the acoustic response characteristics and to assess the engineering properties of the sediments were provided through earlier sampling programs and by cores retrieved based on guidance from this seismic survey. Figure 6 presents all core locations for the analysis. Table 1 lists all cores providing the core name, position coordinates, and date collected.

Core locations for this study (cores KHV-31 through KHV-58) were determined after analysis of Pinger grey-scale analog reflection records and SSS records, which were obtained during the survey. Locations were selected based upon one or more of the following criteria:

a. Observance of a large area of similar material signatures.

b. Observance of a significant change of material signature between two areas.

c. Convergence of distinct subbottom layers at or near the bottom surface.

d. Areas of anomalous bottom or subbottom signature.

e. Specific seismic equipment calibration sites.

Vibracore samples were collected by Alpine Ocean Seismic Survey, Inc. (AOSS), under contract to the Philadelphia District. Twenty-seven vibracore samples were collected during 7-17 June 1993 to depths of 20 ft below the ocean bottom. Core positioning was determined using DGPS. Scientific Environment Application, Inc., was subcontracted by AOSS to perform the geotechnical evaluation. A final report of the vibracore sampling collection and geotechnical testing was delivered to the Philadelphia District in August 1993, and then subsequently sent to WES.

Overview of Sediments

The AOSS core logs and sediment gradation curves are provided in Appendix A. The geotechnical testing of selected sections of each core included grain size analysis using sieve analysis down to the No. 200 sieve and hydrometer analysis for finer sediments; determination of specific gravity and percent moisture; penetrometer records; and classification of sediment samples according the Unified Soil Classification System (USCS). Further analysis of the data was conducted by WES to characterize the sediments in a manner suitable for correlation with acoustic data. This included conversion of grain sizes to the ϕ-scale and reclassification of the sediments in both the Wentworth and Shepard classification systems. Since geoacoustic data can be found in any or all of these sediment classification systems, these data are presented in each system for possible use in other studies. Mean grain size was computed as the average of the D_{84}, D_{50}, and D_{16} sizes. Table 2 presents an overview of specific engineering properties of each sediment sample collected.

A thorough study of Table 2 reveals apparent differences in the sediment type among the three classification systems for several of the sediment samples. These differences are usually attributed to the specific classification technique employed for each system. Figure 10 compares the Wentworth and USCS grain size classifications. The Wentworth system is based strictly on mean grain size, and the grain size categories for the Wentworth scale are slightly coarser than those for the USCS. For sample 3 of core KHV-38 a computed mean grain size of 0.338 mm (1.565 phi) is classified as a medium sand on the Wentworth scale and a fine sand in USCS. The Shepard and USCS sort the sediments by percent distribution of sands, silts, and clays. Figure 11 presents the Shepard graph for this sample. Based on the sand/silt/clay distribution of 78, 4, and 18 percent, the sample is classified as a clayey sand. The Shepard and Wentworth systems do not allow for assessments of sorting like the USCS, precluding the additional classification in terms of poorly graded to well-graded material distributions with these systems. Finally, another cause for some of the discrepancies involves how silt/clay distributions were determined. In some cases, 100 percent of the sample is not accounted for on the gradation curves. For the previous sample (refer to the gradation curve for KHV-38, sample 3 in Appendix A) the hydrometer analysis stopped at a computed grain size of 0.0055 mm with 19 percent of the material finer by weight. The laboratory USCS classification lists this sediment as a silty sand. The WES-derived Shepard classification of a clayey sand resulted from the assumption that the remaining 19 percent of sediment was in the clay range.

Correlation of Sediment Properties: Density versus Mean Grain Size

Because acoustic reflectivity is directly related to the elastic moduli of the sediments as explained in Chapter 2 and in Equation 1, in situ density usually exhibits excellent correlation with measured acoustic impedance. However,

Unified Soils Classification		ASTM MESH	MM Size	PHI Size	Wentworth Classification	
Cobble			4096.00	-12.0	Boulder	GRAVEL
			1024.00	-10.0		
			256.00	-8.0	Cobble	
			128.00	-7.0		
			107.00	-6.75		
			90.51	-6.5		
			76.00	-6.25		
Coarse Gravel			64.00	-6.0	Pebble	
			58.82	-5.75		
			45.26	-5.5		
			38.00	-5.25		
			32.00	-5.0		
			26.91	-4.75		
			22.63	-4.5		
			19.00	-4.25		
Fine Gravel			16.00	-4.0		
			13.45	-3.75		
			11.31	-3.50		
			9.51	-3.25		
		2.5	8.00	-3.0		
		3.0	6.73	-2.75		
		3.5	5.66	-2.5		
		4	4.76	-2.25		
SAND	Coarse	5	4.00	-2.0	Granule	
		6	3.36	-1.75		
		7	2.85	-1.5		
		8	2.35	-1.25		
		10	2.00	-1.0		
	Medium	12	1.68	-0.75	Very Coarse	SAND
		14	1.41	-0.5		
		16	1.19	-0.25		
		18	1.00	0.0	Coarse	
		20	0.84	0.25		
		25	0.71	0.5		
		30	0.59	0.75		
		35	0.50	1.0		
		40	0.42	1.25	Medium	
	Fine	45	0.35	1.5		
		50	0.30	1.75		
		60	0.25	2.0		
		70	0.210	2.25	Fine	
		80	0.177	2.5		
		100	0.149	2.75		
		120	0.125	3.0	Very Fine	
		140	0.105	3.25		
		170	0.088	3.5		
		200	0.074	3.75		
Silt		230	0.0625	4.0	Silt	MUD
		270	0.053	4.25		
		325	0.044	4.5		
		400	0.037	4.75		
			0.031	5.0		
			0.0156	6.0		
			0.0078	7.0		
			0.0039	8.0		
Clay			0.0020	9.0	Clay	
			0.00098	10.0		
			0.00049	11.0		
			0.00024	12.0	Colloid	
			0.00012	13.0		
			0.00006	14.0		

Figure 10. Grain size classification, USCS versus Wentworth scale (modified from *Shore Protection Manual*)

for the Delaware coast study, density was not directly computed for any of the sediment samples. In order to fully calibrate the acoustic model, some assessment of expected density values was needed, especially in evaluating the bottom surface reflection coefficients. To provide density estimates, a relationship between mean grain size and density was developed based on

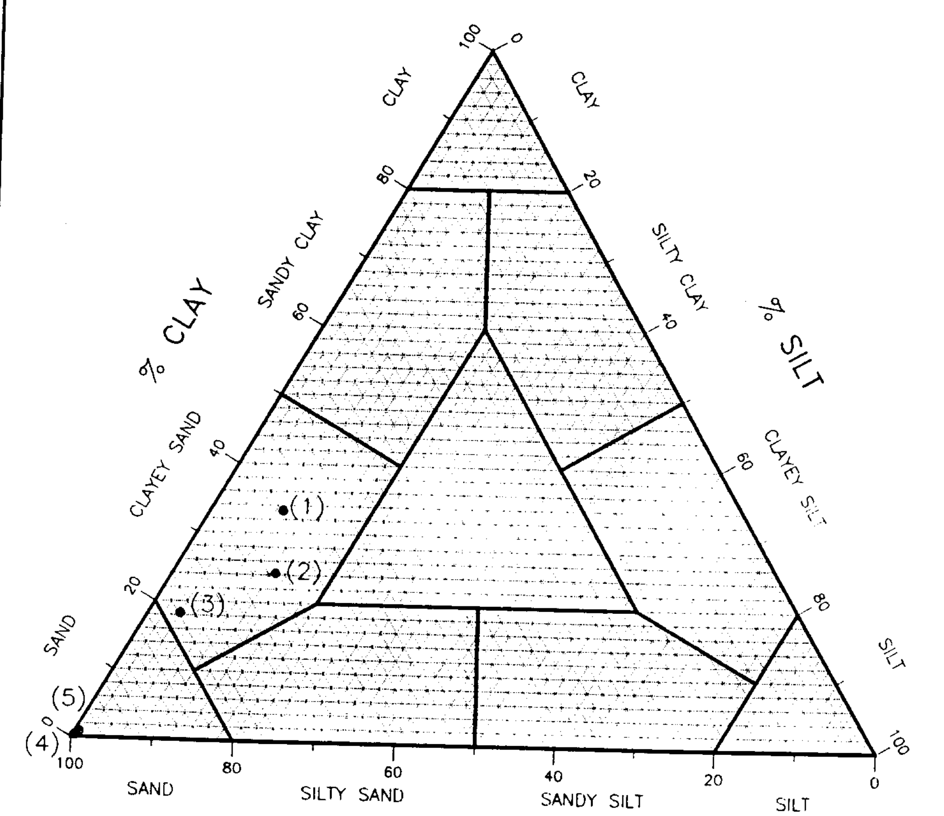


Figure 11. Shepard sediment classification, core KHV-38, sample 3

measured properties from several geoacoustic databases. Specifically, data were assembled from Gulfport Ship Channel, MS,[1] and Panama City Harbor, FL, from laboratory analysis of core samples collected by WES during previous AI studies. Additional data were provided by the U.S. Army Engineer District, Savannah, from core samples collected during an AI investigation of the Savannah Ship Channel, GA (McGee and Sjostrom in publication). Data compiled by Hamilton and Bachman (1982) from the continental shelf and slope are included also. These data are presented in Figure 12.

Figure 12 also presents an empirically derived relationship between density and mean grain size for the predominantly coarse-grained sediments. Only

[1] R. G. McGee. (1991). "Subbottom hydro-acoustic survey of Gulfport Ship Channel," Memorandum for Record, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

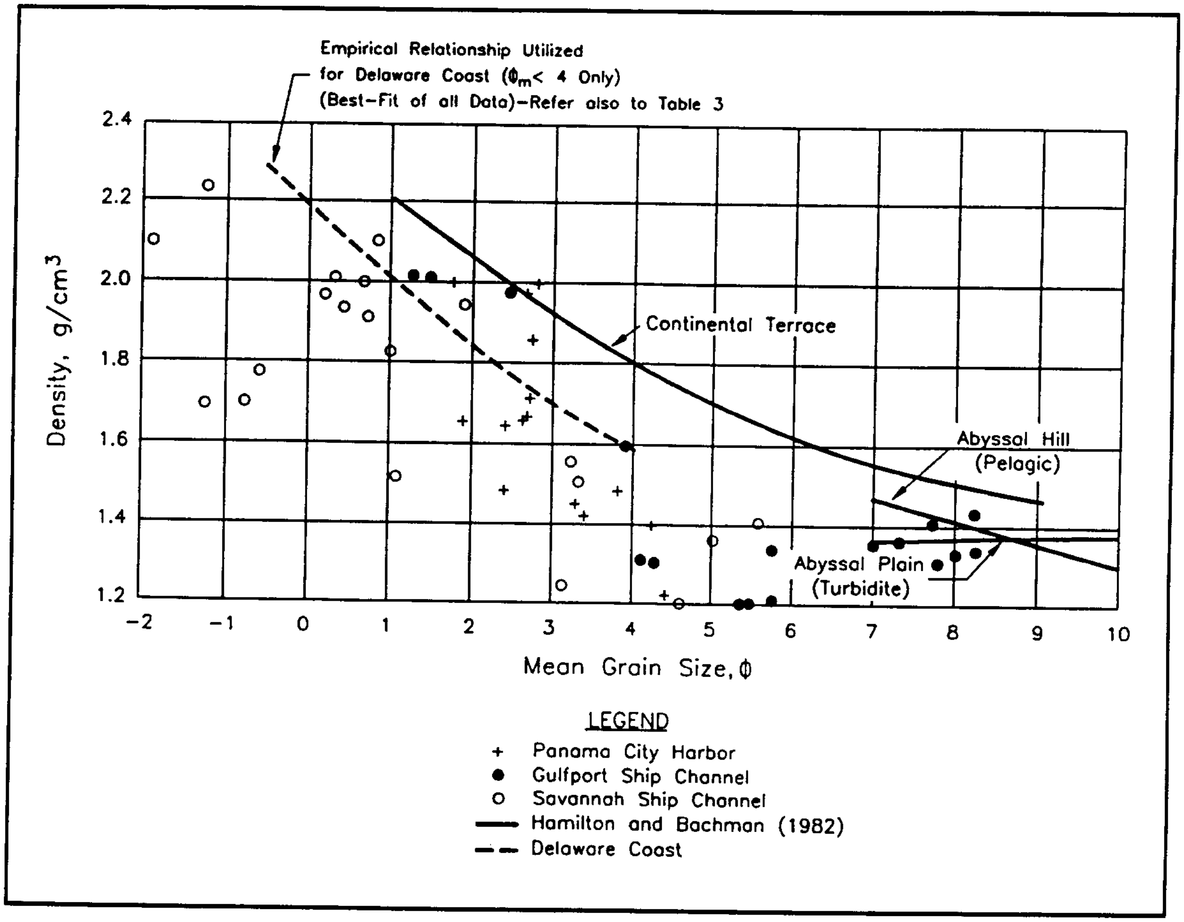


Figure 12. Empirical derivation of mean grain size versus density

sediments described as mostly sand (ϕ sizes < 4) are included in the empirical derivation since laboratory analysis of fine-grained sediments (silts and clays) was performed on only a limited number of the core samples. Also, significant differences in the density relationships exist between coarse- and fine-grained sediments. According to Hamilton and Bachman (1982), these differences are caused by a number of interrelated factors. In summary, these include grain size, uniformity of grain size, grain shape, packing of grains, and mineralogy. This is evidenced in Figure 12 for Hamilton and Bachman's data where a distinct difference in the density-grain size relationships is observed for sediment sizes greater than and less than ϕ of 4. For the sand sizes, density has been found to generally increase with increasing grain size. However, due to the factors just stated, significant differences in the density-grain size relationship can be encountered among various sediment environments. For example, a best fit of the data in Figure 12 for mean grain sizes between 4ϕ and 10ϕ would result in an increase in density with decreasing grain size. A possible explanation as put forth by Hamilton and Bachman is that sand-sized particles are too large to be affected by cohesive forces and density tends to be largely a function of packing. In fine-grained materials, such as silts and clays, distinctly different mineral structures from coarse-grained materials are formed, where density is controlled through cohesive forces acting on the structures. This results in distinctly different relationships between sediment properties, i.e., density and grain size.

Due to the lack of sufficient sample data from the Delaware coast for sediments finer than 4ϕ, no delineation of density ranges related to grain size was attempted for grain sizes greater than 4ϕ.

The empirical relationship for density and mean grain size used for the Delaware coast is derived as a best fit of all data points presented in Figure 12. The Hamilton and Bachman data are not used due to possible effects of sample origin on the derivation. Referring to Figure 12, there seems to be a significant difference between the relationship developed by Hamilton and Bachman for sediments from the deep-ocean environment of the Continental Terrace and that by this researcher from primarily shallow marine sediments from the very nearshore and continental shelf environments. Sediment mineralogy, grain shape, uniformity, packing, and size can vary significantly between sediment environments, requiring that sediments similar in origin be used for derivations of this nature.

The Delaware coast sediment characterization used to relate density, mean grain size, and soil type is summarized in Table 3. In general, the categories established delineate the predominantly clay, silt, and sand sediment types. However, sediment mixtures, such as clayey sands and silty sands, can exhibit uncharacteristically high or low density values. Also, the mean grain size parameter may not always completely describe actual sediment conditions. Factors such as sorting and grain size variability are not necessarily reflected in the mean grain size parameter. The present state of geoacoustic technology really does not allow for the microdelineation of all grain size parameters. It does, as will be shown, provide good characterization of the general nature of the insonified sediment structure.

6 Phase IV: Geoacoustic Modelling

Using calibration procedures for data with high S/N ratios, seismic reflection data are processed to provide estimates of the density, mean grain size, and soil type of bottom and subbottom sediments. Calibrations are performed by correlating acoustic impedance values calculated from the seismic reflection data at a sample location with the measured information (density, mean grain size, etc.) at that location. Experience to date has shown that calibrations made at a few locations within a geologic region provide the necessary shallow seismic parameters to accurately calibrate and describe the entire region.[1] Calibration of the acoustic reflection data for the Delaware coast survey is briefly described in the following paragraphs.

Equipment Calibration: Sources and Receivers

Sonar equations

The geoacoustic parameter calibration procedure begins by determining the total acoustic energy incident at the bottom surface. This basically involves determining the precise reflection coefficient for the first reflector (bottom surface) and its associated acoustic bottom loss for a given sediment. Since the sound velocity of water and its density can be readily measured, the absolute impedance of the water can be calculated. Knowledge of the reflection coefficient, which by the way is completely independent of frequency, from the water bottom interface allows direct computation of the absolute impedance of the first layer of the bottom. The total energy produced by the source, or source wavelet, must be known absolutely. This is accomplished through use of a calibration hydrophone allowing determination of source level *SL* and the transmission losses associated with underwater acoustic wave propagation through the *sonar equations*. The sonar equations, discussed thoroughly by Urick (1983), describe the quantitative effects on sonar equipment created by the many phenomena peculiar to underwater sound

[1] R. G. McGee. (1991). "Subbottom hydro-acoustic survey of Gulfport Ship Channel."

production. These equations are both design and prediction tools for underwater sound applications and relate the effects of the medium, the target, and the equipment. The general sonar equation is given as follows:

$$S_R = SL - N_w - N_{hyd} + N_A + DI + BL \tag{3}$$

where

S_R = bottom reflection energy at receiver, db

SL = total energy of source, db

N_w = 20 x $\log_{10}$ (range, meters), db (transmission loss due to spherical spreading along the path of propagation)

N_{hyd} = receiver sensitivity, db

N_A = amplifier gain, db

DI = directivity index of receiving array, db (function of transducer beam pattern)

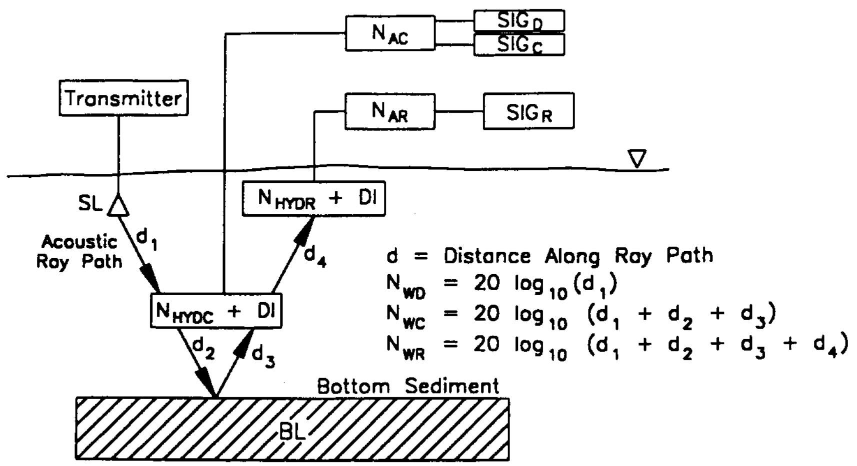
BL = bottom loss, db = 20 $\log_{10}(R)$

R = reflection coefficient

Figure 13 is a detailed depiction of the physical elements in a normal calibration and bottom reflection sonar equation solution case. The N_A value includes all preamplifiers and amplifiers and is obtained from the electrical calibration of the receiving equipment. The calibration hydrophone receiver sensitivity N_{hydc} is available from manufacturers of the hydrophone and should be traced to the ANSI Standard (Acoustical Society of America 1988). The receiving hydrophone array sensitivity N_{hydr} may also be available from the manufacturer or can be easily calibrated in the field using the calibration hydrophone and an alternate form of the sonar equation. This procedure will be discussed in detail later in this report.

Directivity index

The DI is a function of the beam pattern of the transducer array and is an indication of the amount of the total signal the hydrophone is permitted by its sensitivity pattern. The higher the DI, the more discriminating the hydrophone is against signals arriving from directions other than along the acoustic axis. Figure 14a presents the directional pattern of the MASSA Model TR75-A transducer used with the pinger system. Because the transmitter and receivers are horizontally offset, as explained in Chapter 3, the DI becomes a



Note: Refer to Equation 3 for Definition of Terms

SONAR EQUATIONS:

$$SIG_R = SL - N_{WR} - N_{HYDR} + N_{AR} + DI + BL$$
$$SIG_C = SL - N_{WC} - N_{HYDC} + N_{AC} + DI + BL$$
$$SIG_D = SL - N_{WD} - N_{HYDC} + N_{AC}$$

Where:

SIG_R = Bottom reflection signal from calibration array
SIG_C = Bottom reflection signal from calibration hydrophone
SIG_D = Direct wave signal from calibration hydrophone
N_{AC} = Amplifier gain from calibration hydrophone
N_{AR} = Amplifier gain from receiver array

Figure 13. Elements in acoustic calibration and bottom reflection sonar equation solution

significant parameter due to the reflection angles along the path of propagation. Figure 14b presents the equipment geometry for the Delaware coast survey and its effect on directivity. Figure 14c is the *DI* correction versus water depth for application in the sonar equation.

Source level calibration

The first step in the calibration process is to determine the absolute source level. These data are available from the manufacturers of some sonars. Unfortunately, many seismic systems do not have this information readily available, and even if they did, the field operating conditions vary to such an extent that the published levels are not sufficient for precise reflection computations.

The direct wave of the sonar source level is calibrated by writing the sonar equation for the measurement of the direct wave via the calibration hydrophone as follows:

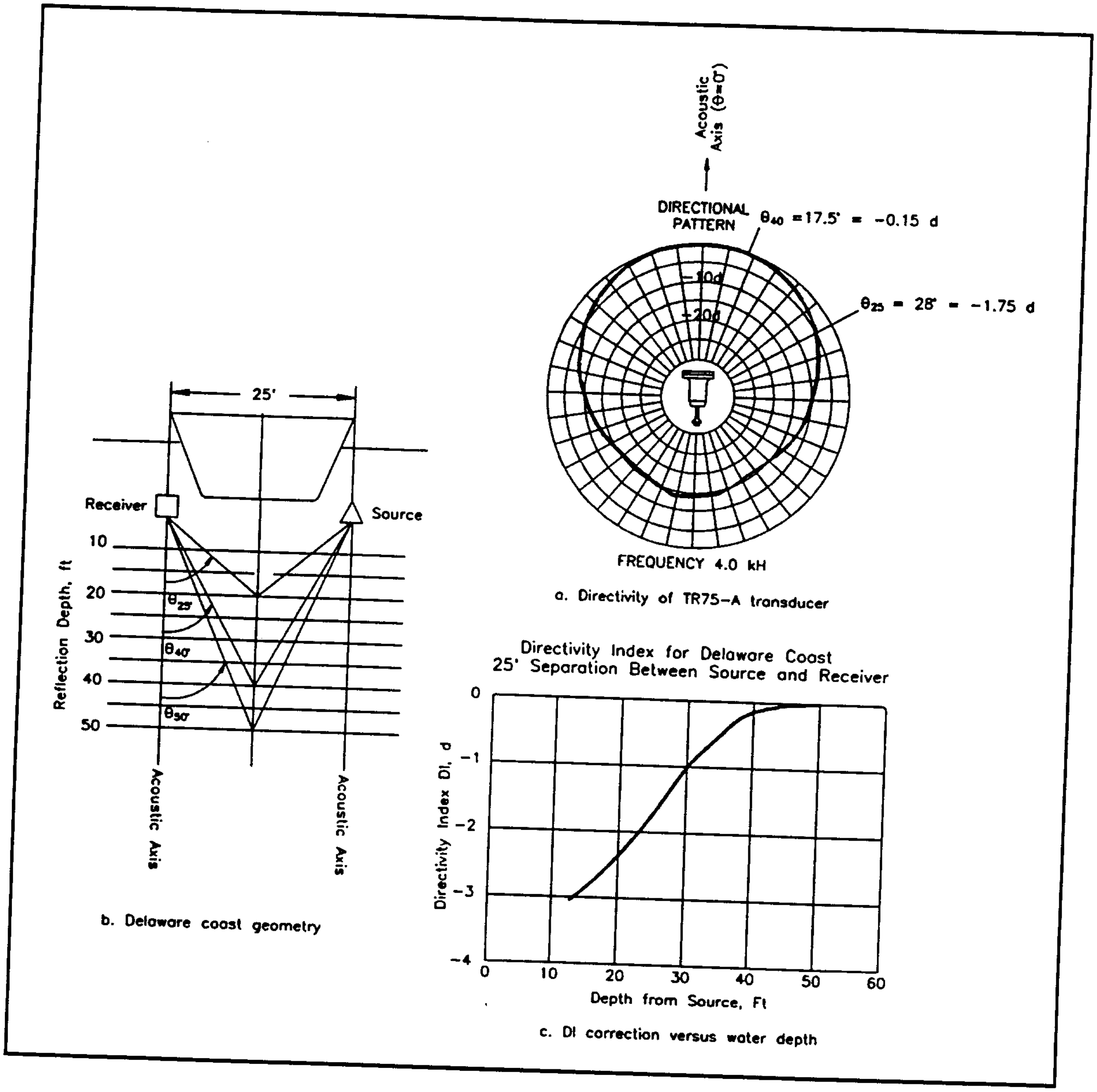


Figure 14. Computation of *DI* versus water depth and ration transducer separation

$$S_D = SL - N_{wdir} - N_{hydc} + N_A \tag{4}$$

where

S_D = direct wave signal level, db

N_{wdir} = transmission loss between source and calibration hydrophone, db

All the terms in Equation 4, except *SL*, are either absolutely known or directly measured. Therefore, solving for *SL*, the absolute source level is determined. Figure 15 presents a typical seismic system calibration data plot. This single

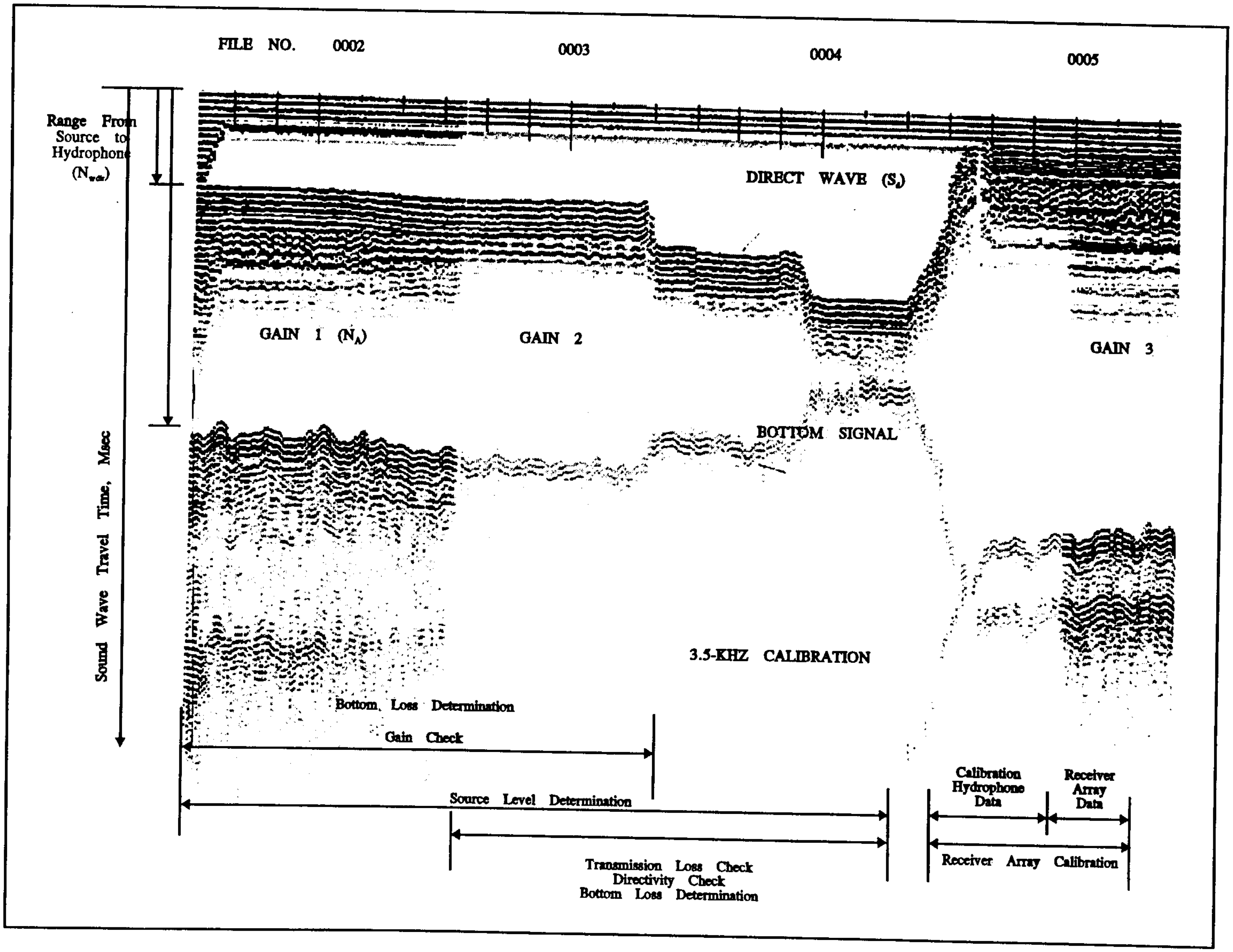


Figure 15. Typical acoustic calibration record

data record contains all the field data required to completely calibrate all aspects of the equipment operations and provide calibration data for the surface sediment impedance. The *SL* calibration is performed using the data between file number 0002 and 0004 where variations in amplifier gain and hydrophone range are occurring.

An example *SL* calculation using the sonar equations is shown in Figures 16 through 18. Figure 16 is the calibration data record for this example (data format similar to Figure 15). The calibration hydrophone ideally should be introduced into the sound field along the acoustic axis of the source. However, this was difficult to accomplish much of the time due to currents and boat drift. The calibration hydrophone was not rigidly deployed, rather, lowered into the sea by the signal cable, resulting in significant drift of hydrophone position. The geometric arrangement had to be measured, and then the actual position of the hydrophone was determined by triangulation relative to the source. Unfortunately, as shown in Figure 17, the hydrophone was located at the very edge of the beam pattern causing the direct wave data to be outside the projection beam and of little use. This situation was quite typical of all the Delaware coast calibration data. Therefore, a secondary approach incorporating local core data was used to determine the total energy of the source wavelet. Core data from the vicinity of the calibration presented in this example showed coarse sand, which typically exhibits an acoustic bottom loss *BL* of about 8 db. Using this value of *BL* and rearranging the sonar equation, a solution for *SL* was solved from the known *BL*. Figure 18 presents the sonar equation computations and statistical evaluation of forty consecutive soundings from a digital subfile of the calibration data. This analysis was accomplished at six different sites throughout the survey area. The following tabulation lists the summary of all calibration sites for *SL* for the operating conditions used during the survey.

Calibration Location	Output Power, kW	*SL*, db[1] (Peak Detect)	*SL*, db (RMS Energy)	Receive Sensitivity N_{hydr}, db
PCL6	2.5	102	97	-72
PCL4	5.0	105	100	-72
PC12	5.0	103	99	-72
PCL5	5.0	104	100	-72
Avg 5 kW	5.0	104	100	-72

[1] Calibration levels are in db relative to 1 dyne/cm^2.

Receiving hydrophone sensitivity calibration

As with the source level, the array sensitivity of the receiving hydrophones N_{hydr}, must be absolutely known. The field calibration is performed by comparing the signal levels of the receiving array with the calibration hydrophone over the same bottom condition. The calibration hydrophone is located in the

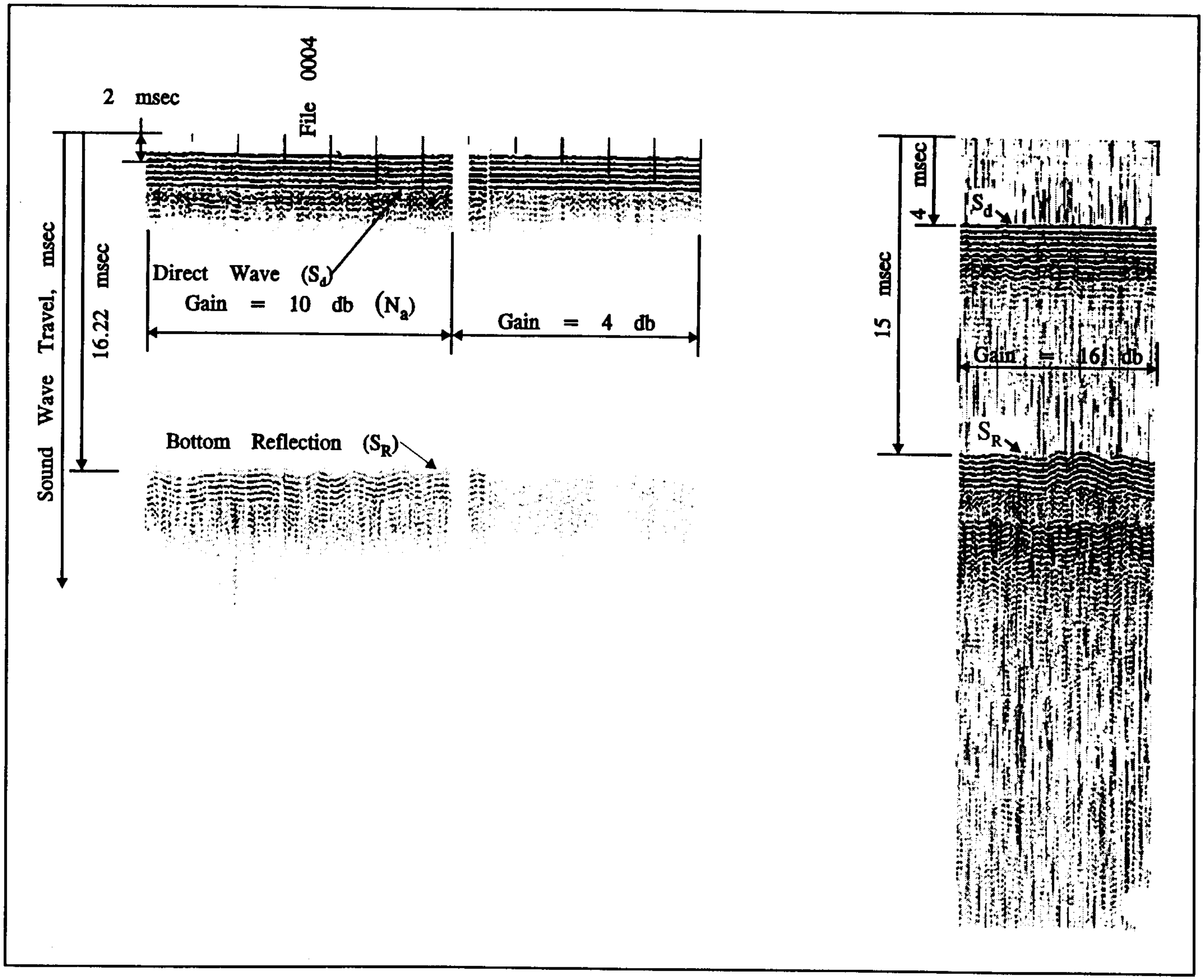


Figure 16. Calibration record site PC12; bottom loss, source level, and directivity determination

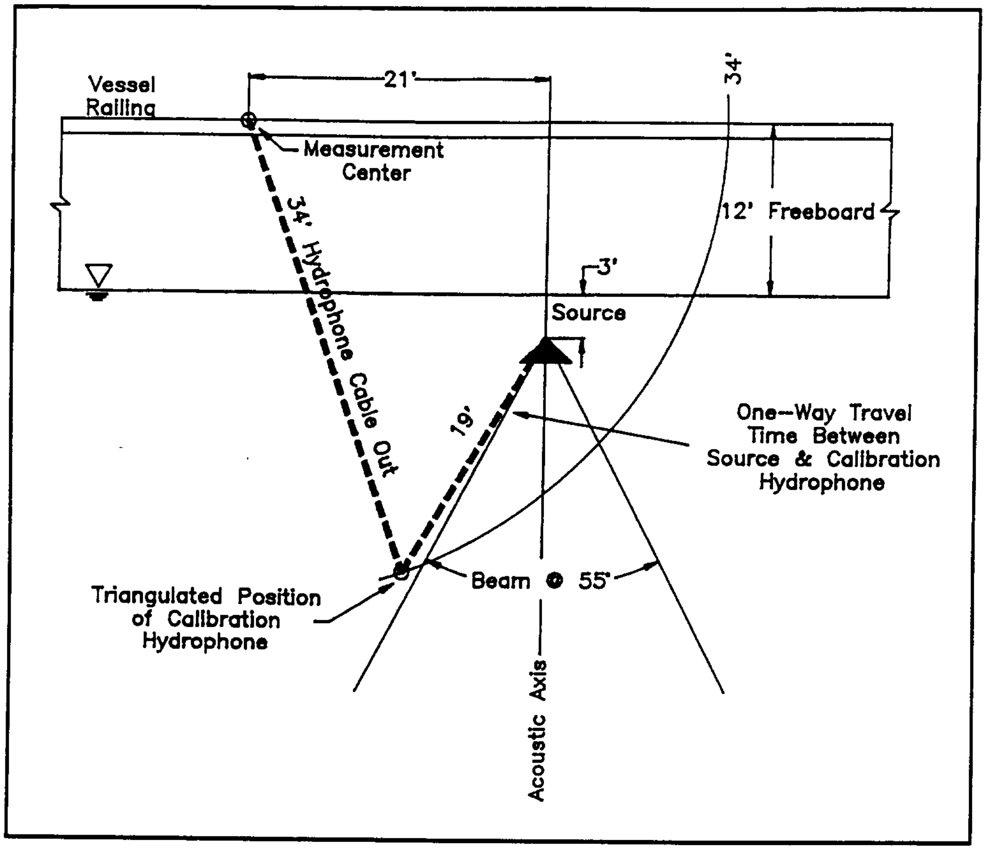


Figure 17. Beam pattern plot and directivity check

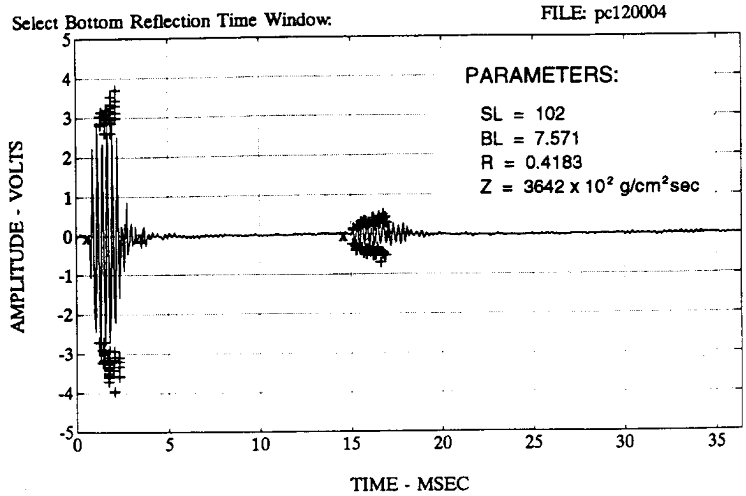
immediate vicinity of the receiving array at the same depth elevation. The sonar equation is designed to solve for N_{hydr} as follows:

$$N_{hydr} = N_{hydc} + S_{Rr} - S_{Rc} - N_{Ar} + N_{Ac} \tag{5}$$

where S_{Rr}, N_{Ar}, and S_{Rc}, N_{Ac} are the receive signals and amplifier gains for the receiving array and calibration hydrophone, respectively. The H_{hydr} for the array used for the Delaware coast survey has been calculated and verified over numerous projects to be -72 db relative to 1 dyne/cm^2.

Determination of Bottom Loss and Surface Reflection Coefficient

The bottom surface characteristics are evaluated through the sonar equation by rearranging Equation 3 to solve for BL as follows:



CALIBRATION: SL & BL FROM CAL DATA
FILE: pc120004

Amplifier Gain (dB):	**10.00 dB**
Hydrophone Sensitivity:	**-86.00 dB**
Range of Direct Signal:	**2.55 meters**
Range of Bottom Reflection:	**23.89 meters**

Trace #	SIGdir	SIGbot	SL	BL
1	9.90	-8.75	101.15	6.56
2	9.26	-4.72	99.75	0.61
3	9.64	-9.58	100.89	7.06
4	10.57	-9.08	101.22	6.85
5	10.35	-9.87	103.18	9.31
6	10.52	-10.59	103.35	10.13
7	10.39	-9.87	103.22	9.58
8	9.84	-7.92	102.17	6.67
9	10.11	-8.53	101.06	5.97
10	9.74	-10.41	102.08	9.12
11	9.88	-8.55	100.83	5.77
12	9.70	-6.69	103.23	6.26
13	10.12	-8.67	102.33	7.35
14	10.58	-7.64	102.79	6.86
15	10.09	-9.51	100.74	6.89
16	10.21	-13.31	102.41	12.58
17	9.82	-9.11	100.47	6.00
18	9.49	-6.51	101.02	3.85
19	9.58	-14.41	101.11	12.42
20	9.97	-6.88	102.04	4.96
21	9.20	-10.31	100.59	7.67
22	9.35	-13.21	101.56	11.61
23	9.48	-9.58	99.98	6.03
24	9.10	-9.64	99.10	5.27
25	9.60	-11.86	101.94	10.38
26	9.44	-13.51	100.98	11.38
27	10.00	-7.17	102.84	6.23
28	10.46	-6.95	102.66	5.65
29	9.11	-9.23	100.64	6.27
30	9.86	-9.51	102.20	7.80
31	10.30	-11.07	103.83	11.61
32	10.52	-11.46	103.35	11.14
33	11.21	-7.31	105.28	9.04
34	9.04	-8.17	99.85	4.53
35	9.37	-8.96	100.91	6.32
36	10.15	-7.05	103.68	6.75
37	9.54	-8.87	101.21	6.74
38	11.46	-8.30	104.42	8.92
39	10.79	-8.50	104.32	9.13
40	11.05	-5.66	103.89	5.57
Max	11.46	-4.72	105.28	12.58
Mean	9.99	-8.93	101.96	7.57
Min	9.04	-14.41	99.10	0.61
Std	0.59	2.13	1.44	2.55

Figure 18. SL calibration data for site PC12

$$BL = S_R + N_{hyd} - SL + N_w - N_A - DI \qquad (6)$$

Since all terms on the right side of the equation are now known, BL, and therefore the surface reflection coefficient ($BL = 20 \log_{10} R$) and acoustic impedance, can be readily determined. If the desired result is an assessment of the bottom surface characteristics, the acoustic solution is complete. All that remains is the correlation of the acoustic parameters with the physical sediment properties. BL was evaluated over the entire study area.

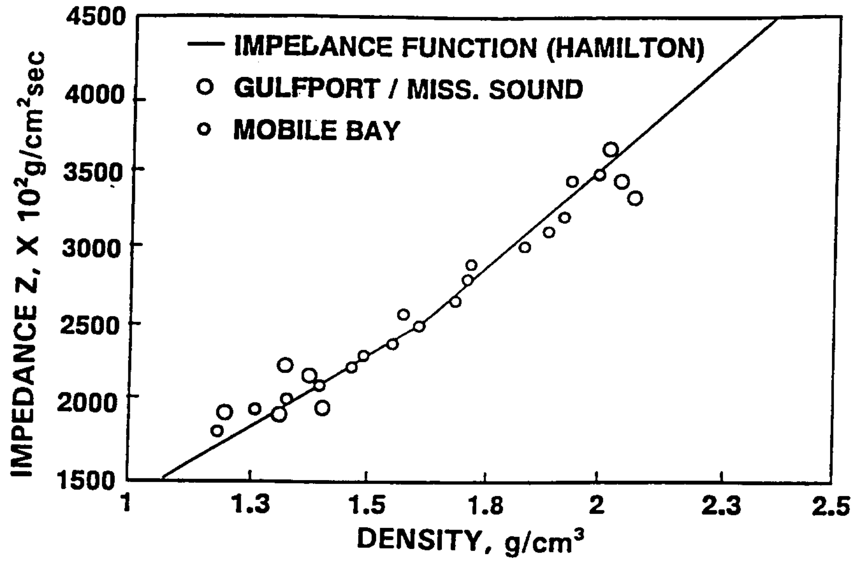
Geoacoustic Relationships

Impedance versus density model

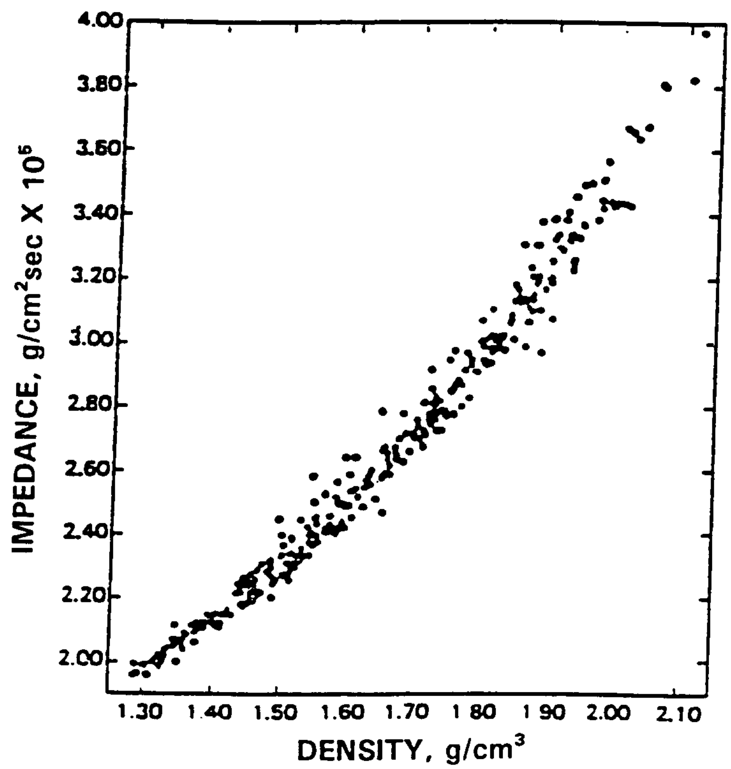
As explained in Chapter 5, no measurements of density were performed on the core samples, thus requiring an empirical derivation of impedance versus density from previously established databases. Using impedance versus density relationships from Hamilton and Bachman (1982) and McGee[1] (Figure 19) incorporated with the Delaware coast density estimates from the grain size analysis of Figure 12, an impedance versus density model was developed for the Delaware coast study. Figure 20 presents Z versus ρ. The lower part of the curve ($\rho < 1.6$ g/cm^3) was established from Caulfield's database for fine-grained sediments used in the AC50 program (Caulfield 1992). Impedance measurements up to about 3,200 × 10^2 g/cm^{2}sec exhibit very good statistical correlations. The standard deviation of the data points about the empirical impedance function for impedances below 3,700 is 0.08 g/cm^3, and the 95 percent confidence interval (95 percent of the data is within this limit) is ± 0.10 g/cm^3. Data scatter is more pronounced for values of Z greater than 3,200 × 10^2g/cm^{2}sec. Not enough data points exist beyond 3,700 × 10^2g/cm^{2}sec to adequately assess the statistics above this value.

The impedance measurements and the density estimates varied among core sites where the samples contained sediment mixtures, such as clayey sands, and well-graded (poorly sorted) sediments. For the Delaware coast, this variation was greatest between 1.9 and 2.05 g/cm^2, the sediment range where the clayey sands and some poorly graded (well-sorted) sediments exhibited similar acoustic impedance responses. This is expected since the mean grain size parameter (used to infer ρ for the sands) describes a poorly graded (well-sorted) sediment quite accurately. For well-graded (poorly sorted) sediments and sediment mixtures, mean grain size does not fully describe the sediment condition. The presence of different sediment types within a given sediment unit can have a significant effect on the acoustic response characteristics of that sediment unit. This situation illustrates one limitation in using a strictly acoustic impedance approach. Impedance is based primarily on the total energy in the reflected signal and does not directly consider absorption and velocity, factors that are probably more geoacoustically sensitive to variations

[1] R. G. McGee. (1991). "Subbottom hydro-acoustic survey of Gulfport Ship Channel."



a. From McGee. Hamilton's function modified by Caulfield (1992)



b. From Hamilton and Bachman (1982)

Figure 19. Density versus impedance: General

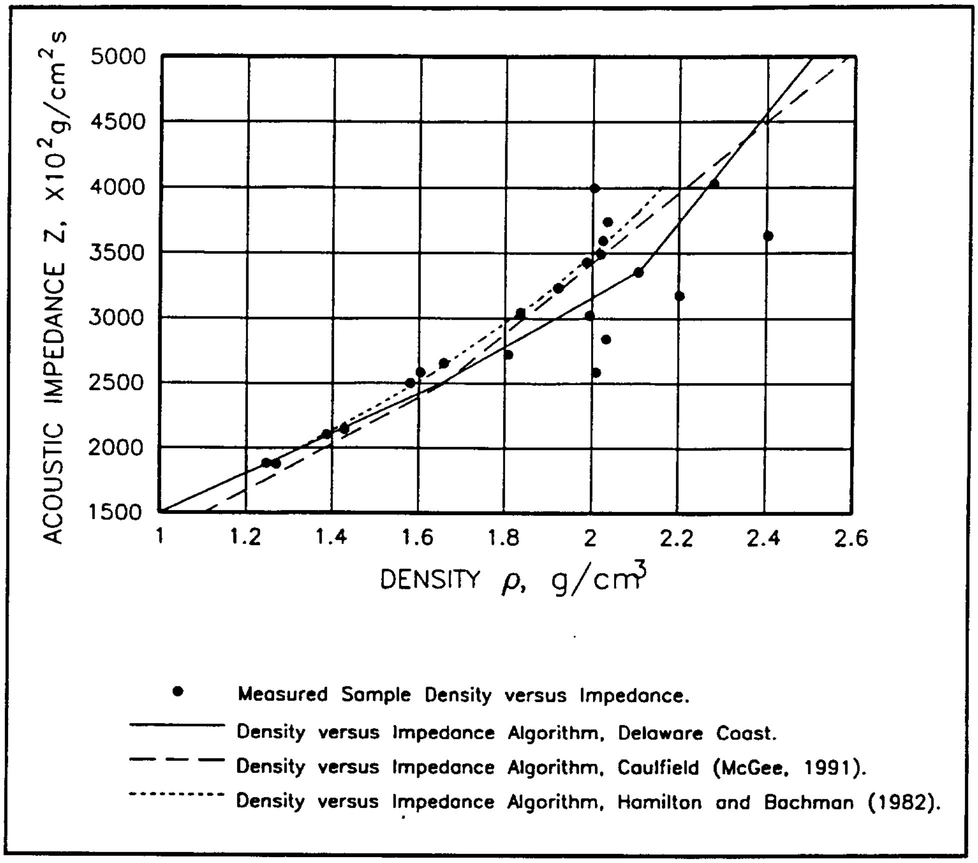


Figure 20. Density versus impedance, Delaware coast

in sediment structures. In the case of poorly graded sands and gravels (sediment grains basically uniform), the impedance measurements and density estimates were quite consistent.

Impedance versus mean grain size model

Using data from Table 4, a general relationship between mean grain size and *Z* was developed to aid in sediment characterization. Figure 21 presents the empirically derived impedance/grain size function for the Delaware coast study. Except for a few data outliers the acoustic impedance exhibits good correlation with the mean grain size parameter. As stated previously, mean grain size does not always fully describe the sediment condition. The presence of different sediment types within a given sediment unit can have a significant effect on the acoustic response characteristics of that sediment unit. In this case, the outliers represent cores containing sediment mixtures (SC, SM) and some well-graded sediments (SW). Poorly graded sands and gravels showed excellent consistency. The mean grain size model does not apply for sediment sizes smaller than 4ϕ.

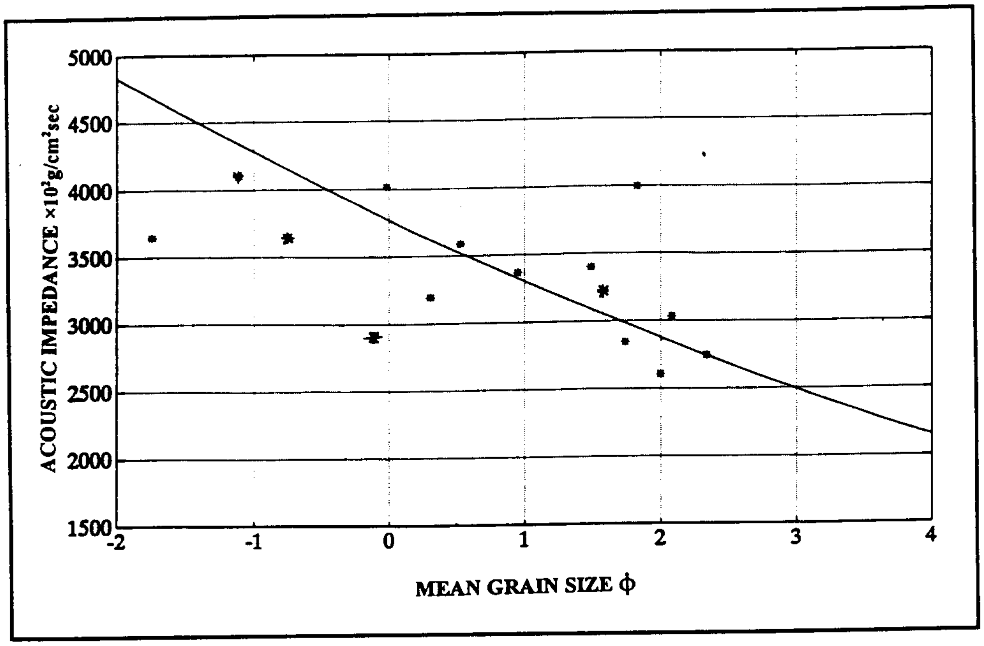


Figure 21. Mean grain size versus impedance: Delaware coast

BL versus sediment properties

Acoustic *BL* was determined at each core site for cores KHV-31 through KHV-58. The *Z* for the bottom surface reflection was determined by computing the total wavelet energy in the bottom reflection signal and substituting this energy for S_R into Equation 6, solving for *BL*. *BL* was then converted to reflection coefficient *R* and *Z* using Equation 2. Figures 22 and 23 present typical bottom *Z* evaluations for core sites KHV-31 and KHV-32, respectively. The figures consist of the pinger reflection record and a plot of the *BL* computations and statistical evaluations versus sequential data files. The mean *BL, RC,* and *Zs* values represent the arithmetic mean of all soundings over the entire record. Individual data points on the plot are the statistical results (mean and ± standard deviation) for the 40 consecutive soundings stored in each data subfile.

The surface sample from core KHV-31 is characterized as a clayey sand (SC) with a computed mean grain size of 2.34ϕ. Based solely on mean grain size, the sample is classified as a fine sand. From Figure 12, the wet density of the sample is estimated between 1.7 and 1.8 g/cm^3. The computed mean *BL* was 10.96 db (Figure 22) with an equivalent R of 0.29. The *Z*, computed relative to seawater (Equation 2) was 2,746 × 10^{2}g/cm^{2}sec. Using the density model of Figure 20, the acoustically derived density is estimated to be 1.74 g/cm^3, within the range of the estimated sample density.

The surface sample from core KHV-32 is characterized as a poorly graded medium to coarse sand (mean ϕ = 0.95) with some round gravels. From the density-grain size relationship established in Figure 12, wet density is

estimated between 2.0 and 2.1 g/cm^3. With a computed mean BL of 8.97 and R equal to 0.374 (Figure 23) the resultant Z for the site is 3,370 × 10^2 g/cm^2 sec. According to the density model, this equates to an estimated density of 1.95 g/cm^3, which is within 5 percent of the estimated in situ density.

This analysis was accomplished for all surface sampled locations summarized in Table 4. These values are for the surface sediments only and are used to calibrate and verify the impedance-density function used for sediment characterization since the surface Z is well-defined. Impedances of the subbottom layers are determined only after all the losses, particularly absorption, have been estimated. Therefore, for development of the impedance function, it was preferable to use only impedance values calculated from absolute acoustic measurements.

Absorption calibration

One of the primary energy losses encountered during acoustic wave propagation through differing media is that due to absorption. This loss involves a process of conversion of acoustic energy into heat and thereby represents a true loss of acoustic energy to the medium in which propagation is taking place. Energy loss due to absorption has been researched extensively for marine sediments through which reasonable approximations of loss are provided. Hamilton and others (refer to Bibliography) present convincing experimental evidence of absorption's relationship to the first power of frequency. Hamilton (1972a) presents the following important observations:

a. Absorption is dependent on the first power of frequency.

b. Velocity dispersion is not important.

c. Intergrain friction appears to be, by far, the dominant cause of wave energy dampening in marine sediments.

Specifically, absorption varies as a function of frequency according to the empirical equation

$$\alpha = kf^n \tag{7}$$

where

α = absorption, db/m

k = attenuation coefficient, db/m/kHz

f = frequency, kHz

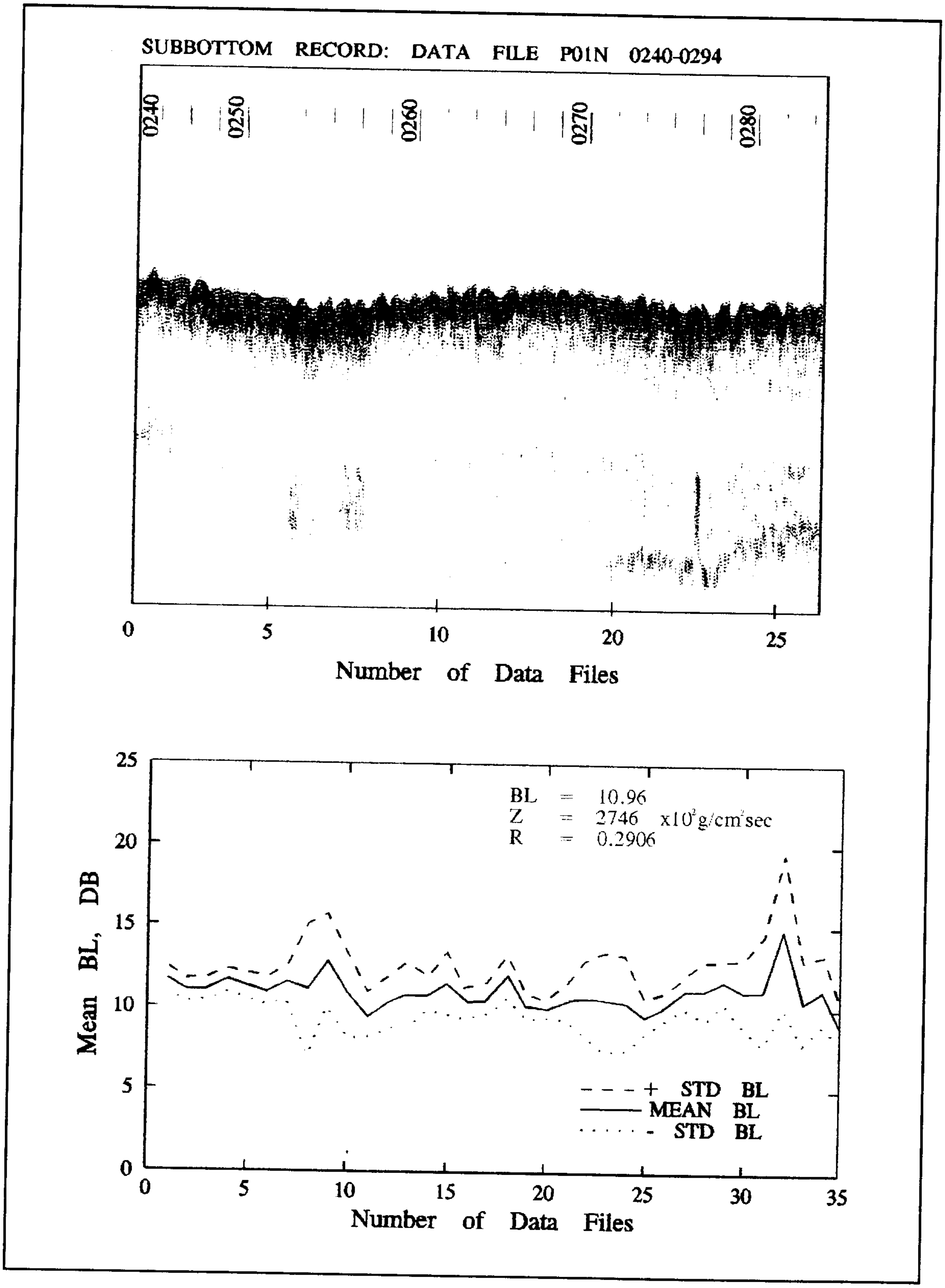


Figure 22. Impedance evaluation: core site KHV-31

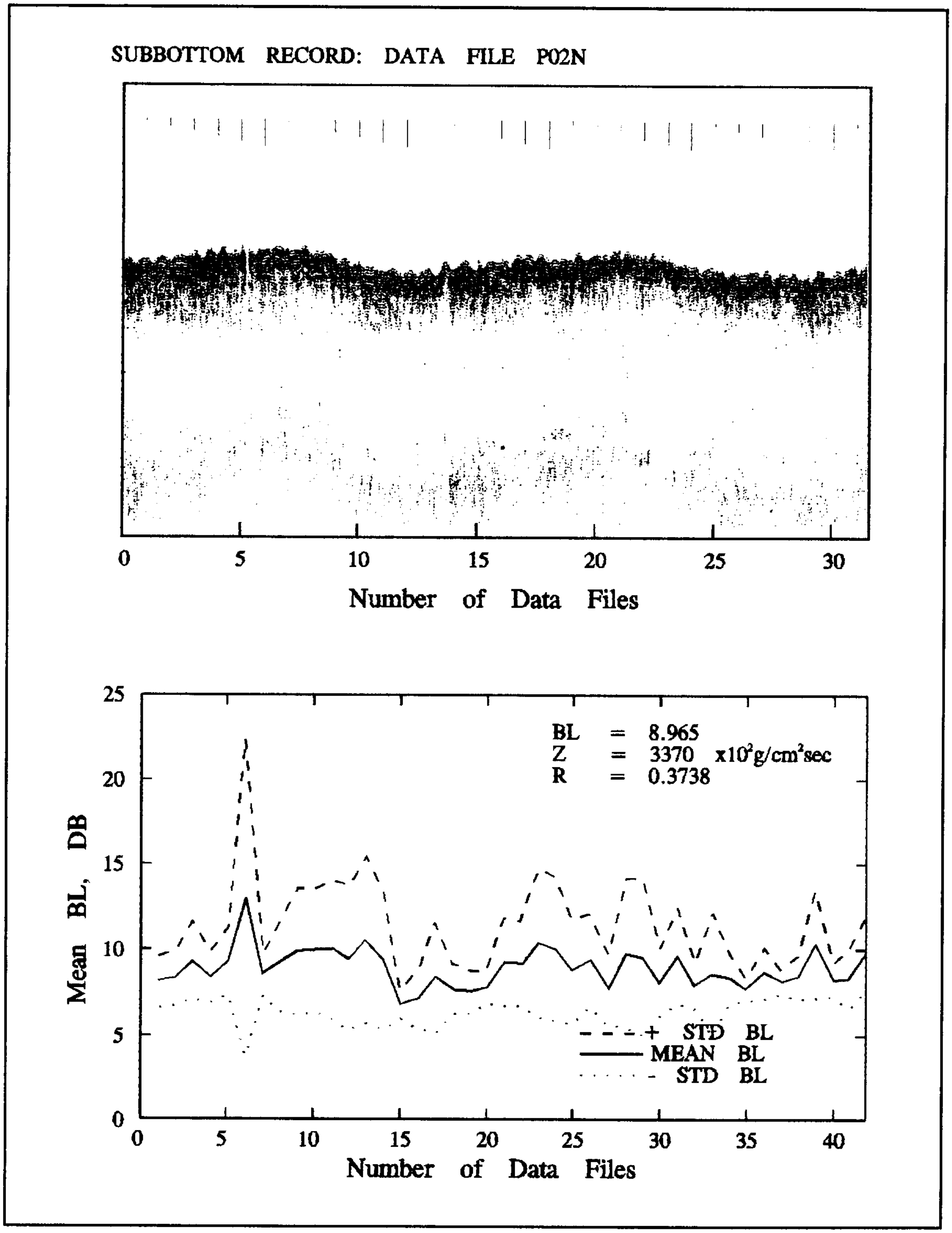


Figure 23. Impedance evaluation: core site KHV-32

n = exponent of frequency

The constant n has been experimentally determined to be essentially unity for the frequencies of interest leaving k in Equation 7 as the only variable. This constant varies with sediment type and is related to porosity and mean grain size as shown in Figure 24. A modification of this model as described by Caulfield and Yim (1983) and Caulfield, Caulfield, and Yim (1985) is used in the AI method to estimate the engineering properties of marine sediments. A reasonable measure of absorption, in keeping with Equation 7, is provided assuming an exponential correction as a function of frequency by

$$\alpha = 10 \log_{10} e^{\frac{\rho(2\pi f)}{kc} \times X} \tag{8}$$

where

ρ = density of layer, gm/cc

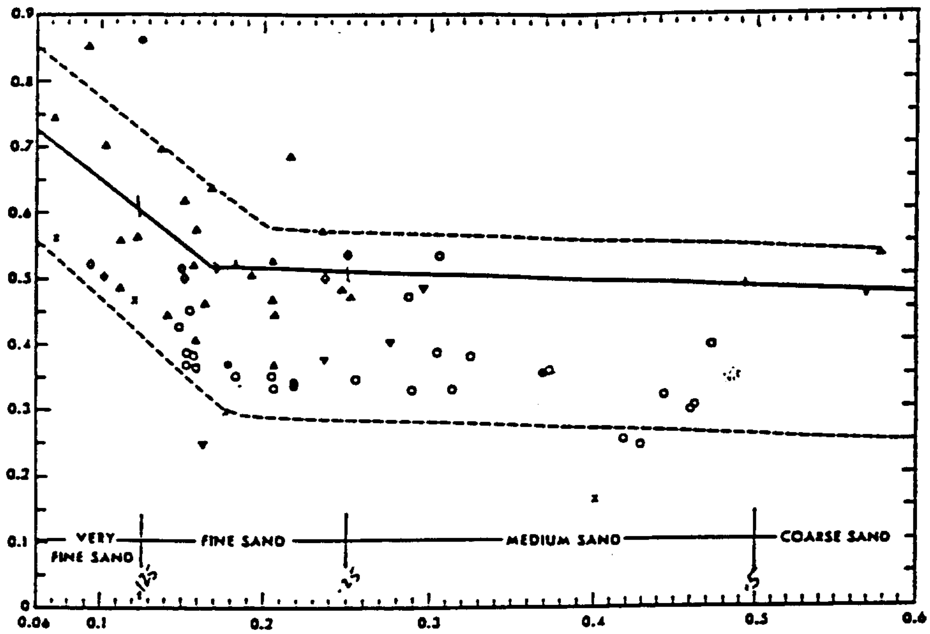
k = attenuation coefficient (similar to Hamilton's)

c = sound velocity of layer

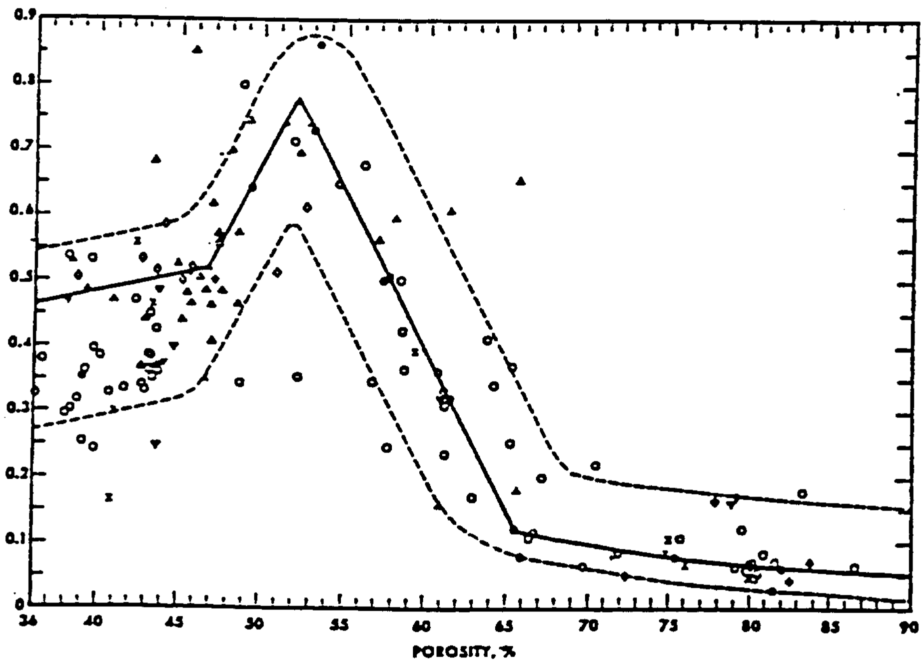
X = precision absorption correction factor

The coefficient k is either experimentally derived or estimated from Hamilton's regression equation (Figure 24), and the correction factor X is included to compensate for localized variations in the absorption properties of sediments in a given geologic setting. This value, termed the absorption factor in the AC50 program, normally remains unity and is altered only when detailed core data are available, providing regional absorption data. The value is increased or decreased so that the deeper impedance estimates match the deeper core properties.

The absorption factor was determined in the Delaware coast study by comparing the rate of absorption in a given sediment across a range of frequencies. Since absorption varies linearly with frequency (Equation 7), the absorption coefficient can be evaluated by matching the impedance of a deep reflector from data of two or more frequencies. This was accomplished with 3,500- and 1,000-Hz data collected along line 7N. Figure 25 presents the subbottom reflection profiles in the vicinity of core KHV-38 for both 3,500- and 1,000-Hz data. The core data (Appendix A and Table 2) show 8 ft of dark brown clayey sand (SC) with shell fragments with a computed mean grain size ϕ_m of 1.83 and an inferred density (from Figure 12) of 1.9 g/cm^3. The computed Z for the surface was $3{,}997 \times 10^2$ g/cm^{2}sec, which is associated with a density value approximately 15 percent higher than that inferred. A density of 2.0 g/cm^3 is categorically associated with a fine sand according to Table 3. As discussed in the section "Impedance versus density model," the presence of different sediment types within a given sediment unit



Mean grain size mm versus k (in $\alpha = kf^1$). Data, symbols, and remarks: same as in caption for Figure 3. Plot of mean grain size in mm emphasizes relationships in sands (see text). Regression equations for solid lines: Coarse, medium, and fine sand, in part (0.6 to 0.167 mm): $k = 0.5374 - 0.1113\ (M_z)$. Fine sand (in part), and very fine sand (0.167 to 0.063 mm): $k = 0.8439 - 1.9431\ (M_z)$.



Porosity n, percent, versus k (in $\alpha = kf^1$). Data, symbols, and remarks same as in caption for Figure 3. Regression equations for solid lines: Coarse, medium, and fine sand (36 to 46.7 percent): $k = 0.2747 + 0.00527\ (n)$. Very fine sand and lower-porosity mixed sizes (46.7 to 52 percent): $k = 0.04903\ (n) - 1.7688$. Mixed sizes (52 to 65 percent): $k = 3.3232 - 0.0489\ (n)$. Silt-clays (65 to 90 percent): $k = 0.7602 - 0.01487\ (n) + 0.000078\ (n)^2$.

Figure 24. Attenuation versus mean grain size and porosity (from Hamilton 1972a)

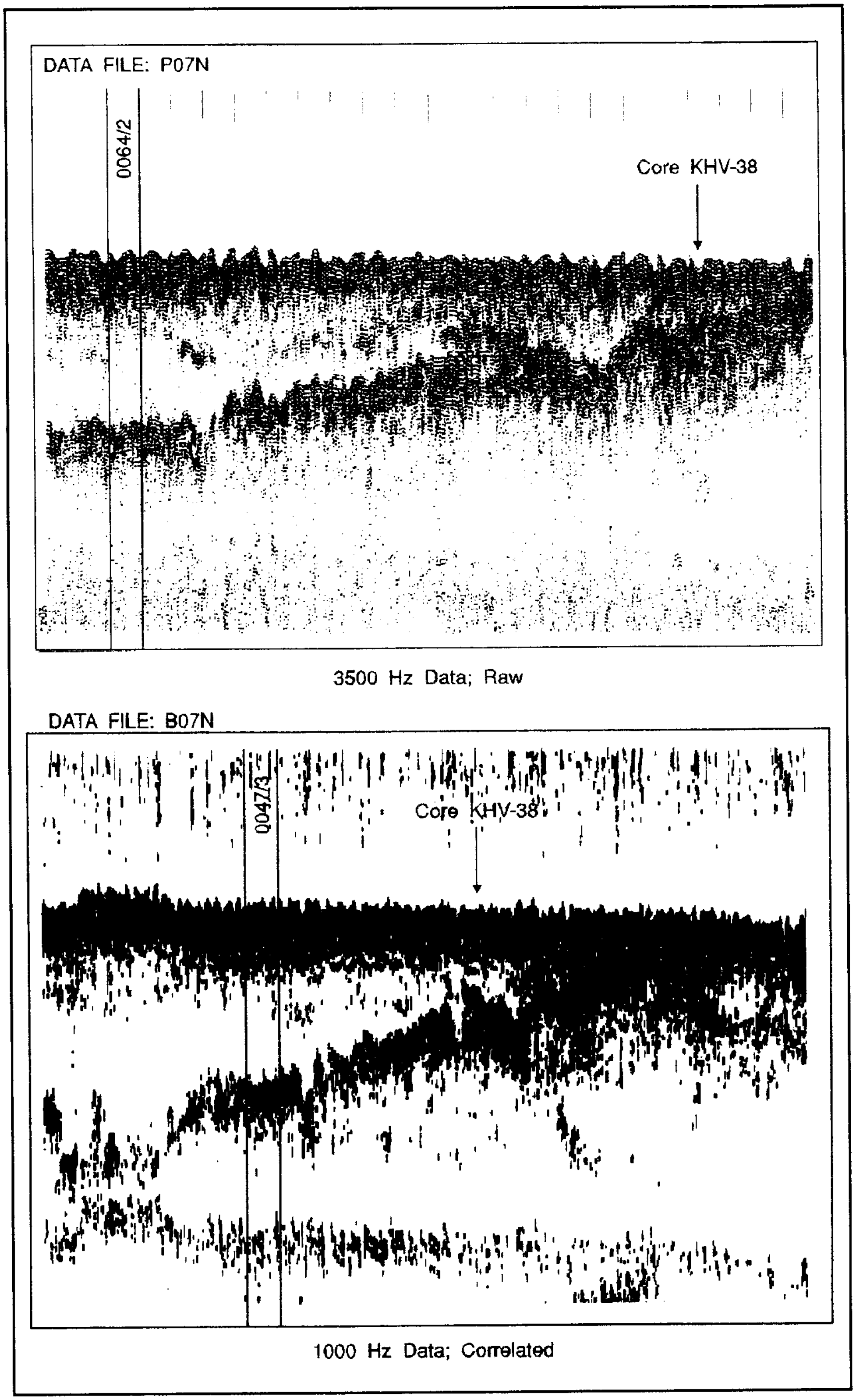


Figure 25. Reflection profiles: 3,500-Hz and 1,000-Hz data near core KHV-38

can have a significant effect on the acoustic response characteristics of that sediment unit. The computed acoustic impedance value supports the apparent density range of the sample. Therefore, a density value between 2.0 and 2.1 g/cm^3 was used for surface analysis in the absorption calibration. This uppermost sediment unit overlays successive layers of sand. These sand layers increase in grain size from a silty sand at -9.2 ft (ϕ_m = 1.56) to well-graded coarse sand and gravel (ϕ_m = -1.26).

The AC50 program was used to conduct the absorption calibration by varying the absorption factors for the data at both frequencies until impedance calculations of the subbottom horizons for each frequency source were matched. The data files chosen for the absorption analysis (files P07N0642 and B07N0473 for the 3,500-Hz and 1,000-Hz data, respectively) were offset from the actual location of core KHV-38 as shown by Figure 25. This was to get into an area of improved data quality and, more importantly, to maximize the layer thickness above the deepest reflector, improving the absorption calculations. Figure 26 presents the impedance and density estimates for both the 3,500-Hz and 1,000-Hz data at the selected calibration site. The 3,500-Hz results are about 10 percent higher than the 1,000-Hz results at the deeper reflector, due mostly to the relatively poor quality of the 1,000-Hz data compared to that at the 3,500-Hz. The estimated ping-to-ping variability of the total energy in each data trace for the 1,000-Hz data is at best ±1 db, which translates to an approximately ±10 percent repeatability in the results. The geoacoustic calibrations for cores KHV-37 through KHV-39 are presented in Figures 27 through 29, respectively, and show the acoustically derived density and grain size data compared with laboratory-measured values from the core samples. Determinations of mean grain size are within ±10 percent of the measured values for the deepest samples in each core.

The absorption evaluation was further verified through synthetic modeling. This modeling involves creating one-dimensional synthetic seismograms by simply convolving a known wave form, such as the source wavelet measured during calibration, with a reflectivity function derived from actual geologic data. Figure 30 presents the acoustic modeling results for 1,000-Hz data collected in sediments similar to that used in the previously discussed absorption calibration. The main difference was a 5-ft-thick clay layer beginning 16 ft below the surface. A geologic environment was constructed based on initial interpretations of the seismic records and from computations of impedance of the surface sediments using the sonar equations. Engineering properties for each of the sediment units were modeled using the geoacoustic relationships for density, impedance, and grain size for this study. Reflection coefficients for each reflecting horizon were computed using Equation 2 and are listed along with each parameter in Figure 30. The depths are not related to the local datum (mllw) but do accurately represent the actual sediment thicknesses. A reflection sequence was constructed versus depth and the reflection coefficients then convolved with a typical boomer source signature to generate the synthetic seismogram. Note as the sediment layers alternate between softer and harder sediments, the polarity of the reflection coefficient alternates between positive and negative. This very important data characteristic will be discussed further later in this report. An actual boomer time-history plot from

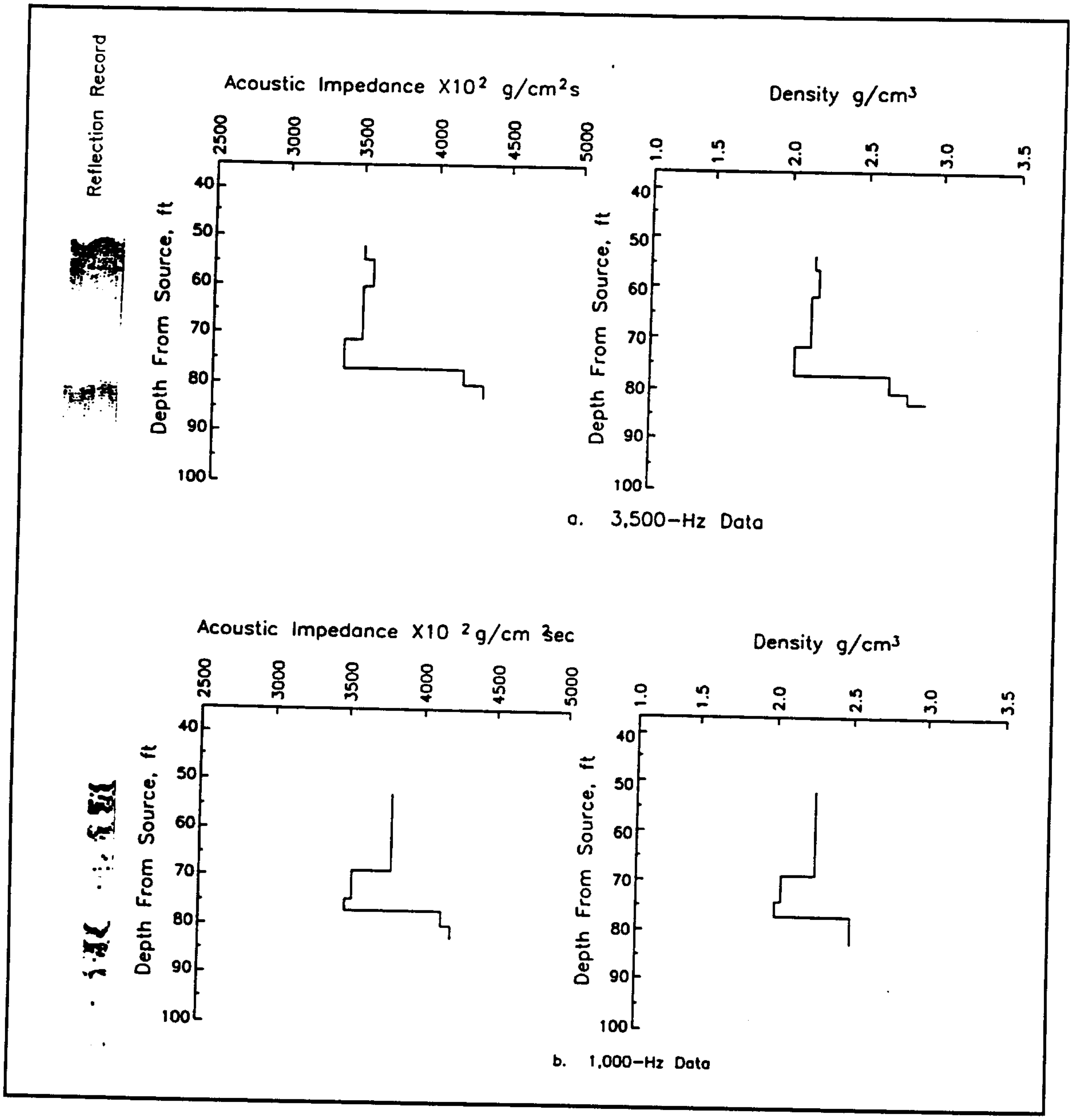


Figure 26. Absorption verification: impedance and density at 3,500 Hz and 1,000 Hz, absorption factor 15, file B07N0473

near the modelling site is presented in Figure 30 and reveals a reflection horizon at each interface. Note, however, that there is no apparent indication of the polarity of the reflection coefficient in the unprocessed reflection trace.

Polarity of reflection coefficient

As shown in the situation described in the preceding section, the nature of the impedance change (higher or lower) at a reflection horizon will produce either a positive or negative reflection coefficient. A negative reflection

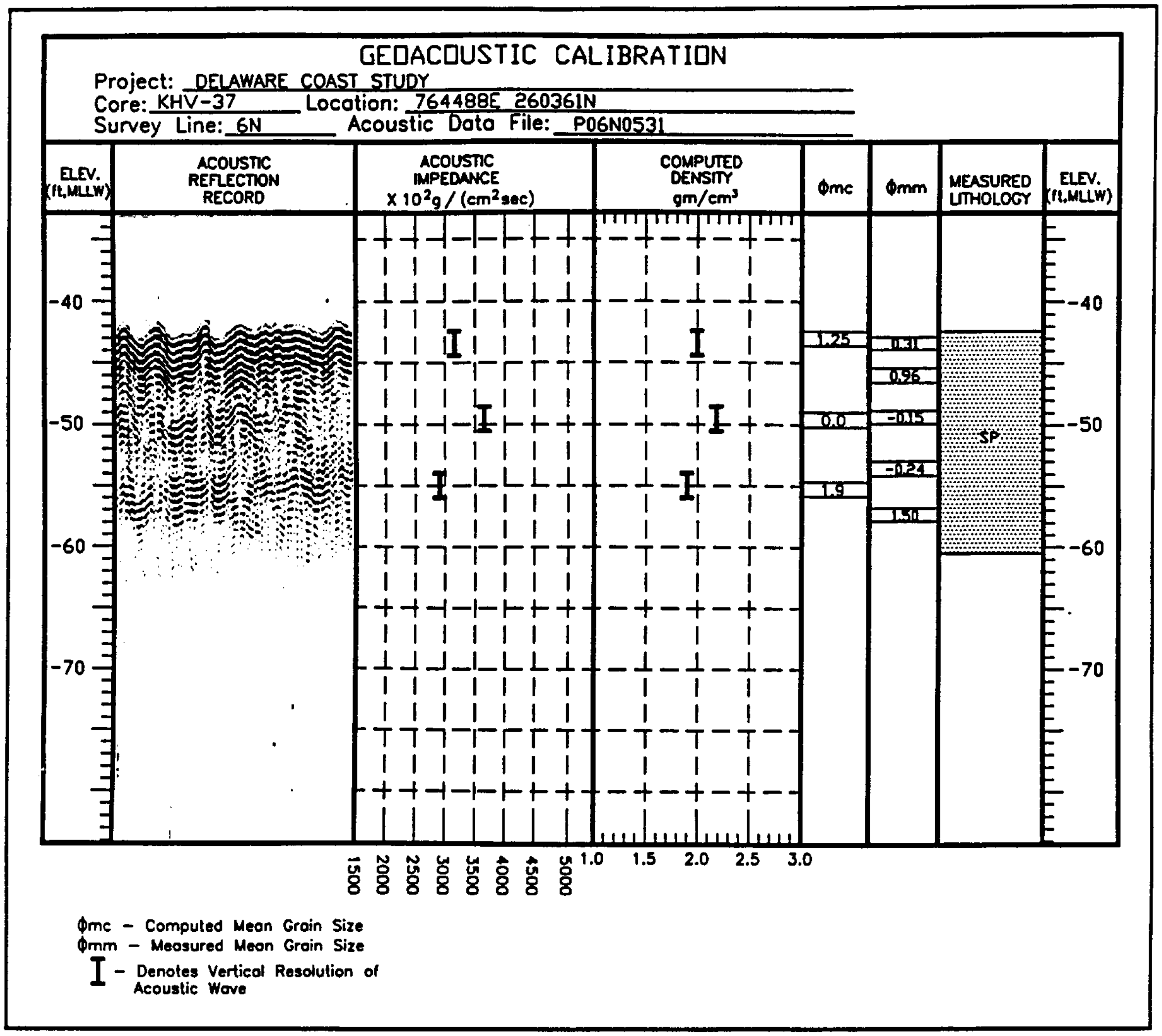


Figure 27. Geoacoustic calibration: KHV-37

coefficient results from the phase change of the reflected signal occurring when the wave reflects off a softer layer. Using match-filter correlation techniques[1] to correlate the source wavelet with the reflected wave, an assessment of the polarity of the reflection coefficient can be attempted. The final plot in Figure 30 presents the same boomer data after correlation with the source wavelet acquired during onsite equipment calibrations. There is some indication of the polarity of the reflection wavelets as shown by the apparent reversing, or flipping, of the wave pattern (quite obvious for wavelet 3 on the figure).

The AC50 program used to analyze the data from the Delaware coast survey does not automatically compensate for changes in polarity of the reflection coefficient. Many of the cores retrieved throughout the survey area were characterized as fine to medium sands overlaying silts and clays. This made

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[1] Correlation technique used is described in Caulfield (1991a) and McGee, Ballard, and Caulfield (1995).

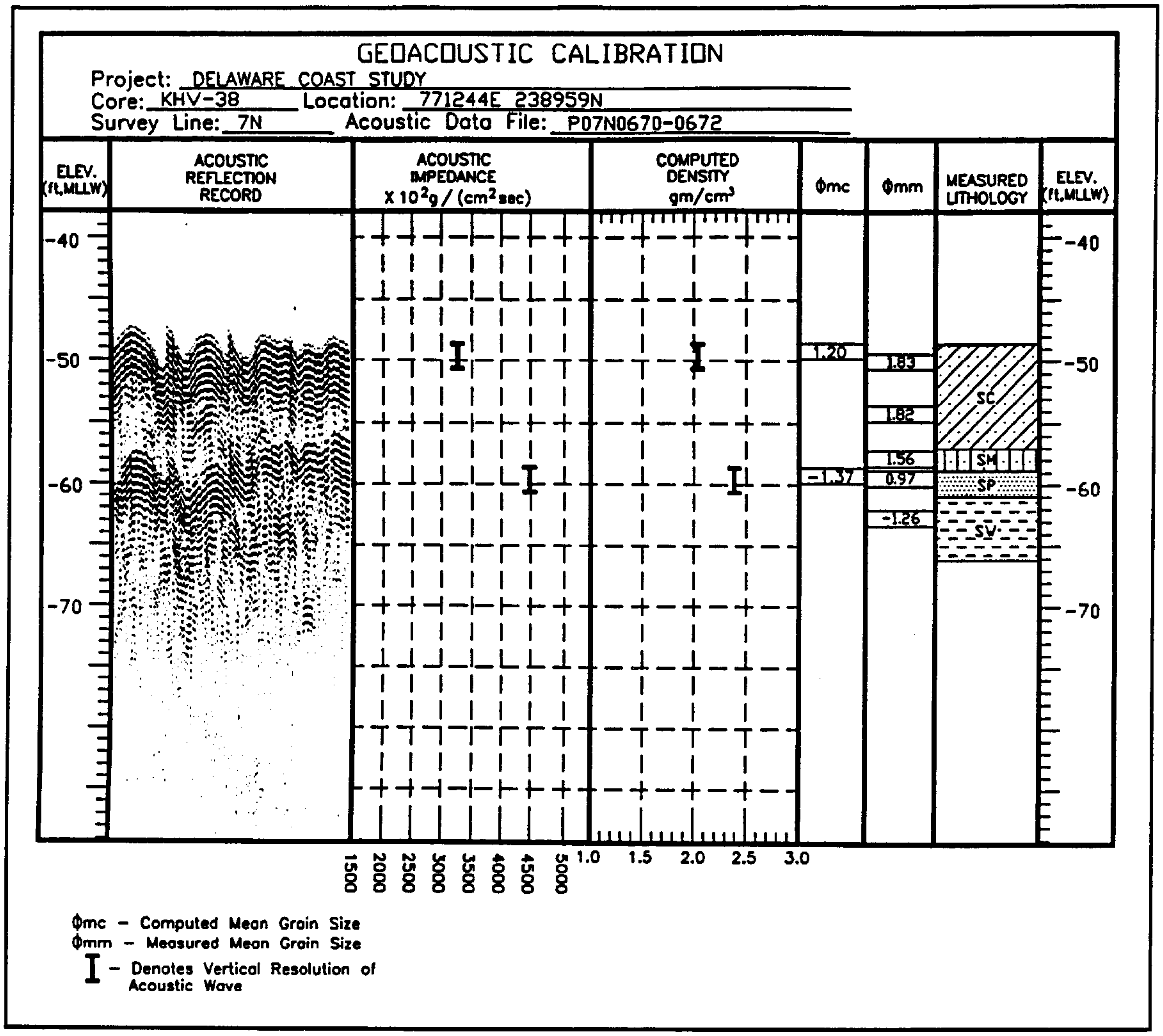


Figure 28. Geoacoustic calibration: KHV-38

processing and analysis of the pinger data quite difficult in many areas, requiring the determination of reflection coefficient polarity (+ or -) outside the AC50 program and applied externally. Verification was provided through core data and by applying certain geoacoustic constraints:

a. *Absorption.* Competent sediments such as sands and gravels exhibit higher rates of attenuation than less competent silts and clays. Therefore, the presence of 3,500-Hz high-amplitude reflectors at depths greater than 10-15 m indicates that softer sediments are most likely present in the subsurface above the deep reflector. Sands and gravels will reflect a high percentage of the incident energy and highly attenuate the transmitted portion, severely limiting the possible depth of penetration.

b. *Reflectivity.* The amplitude coefficient of a reflected wave is a function of the change in impedance between the layers (Equation 2). Therefore, a low-amplitude reflection usually indicates a small change in sediment

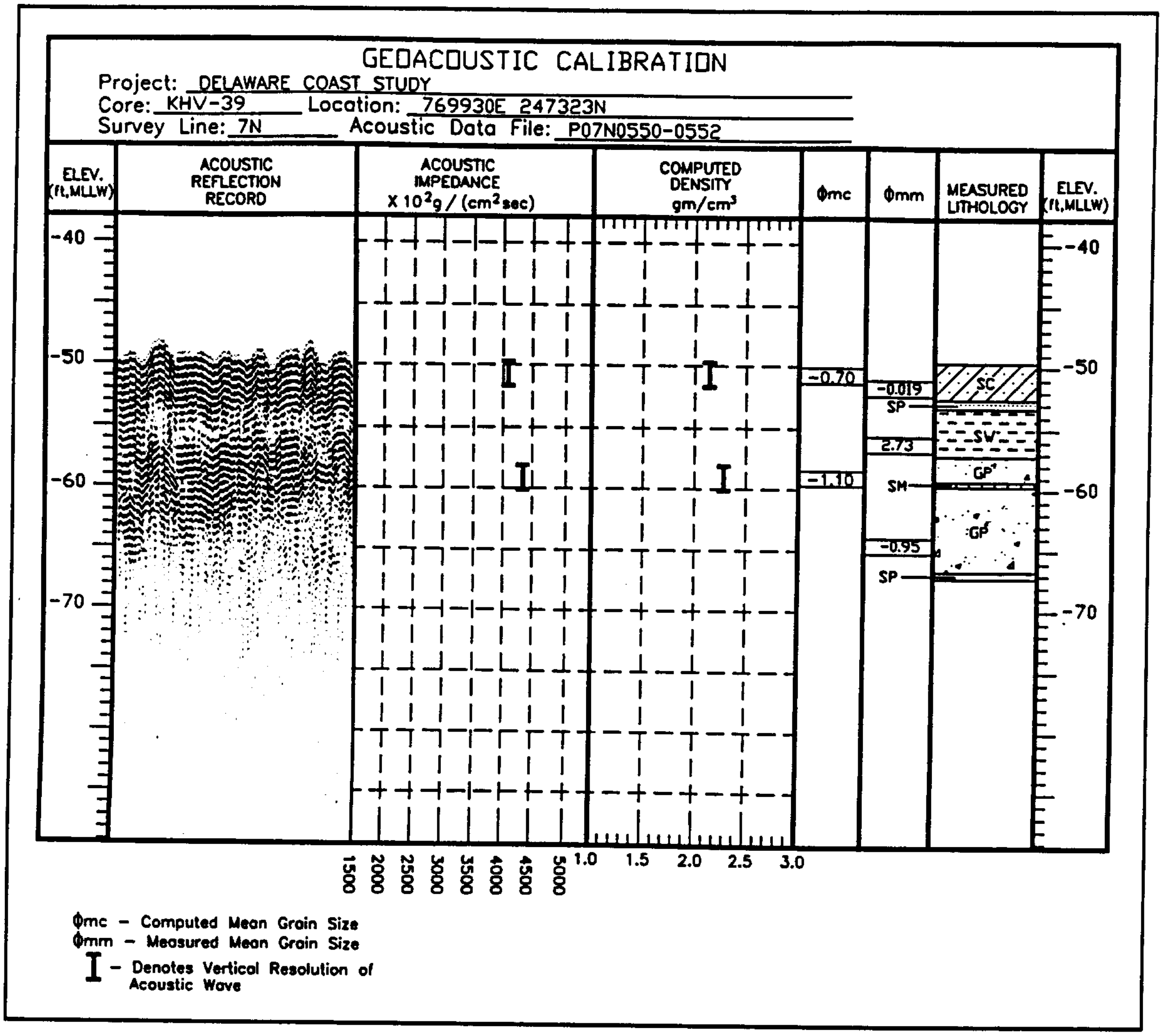


Figure 29. Geoacoustic calibration: KHV-39

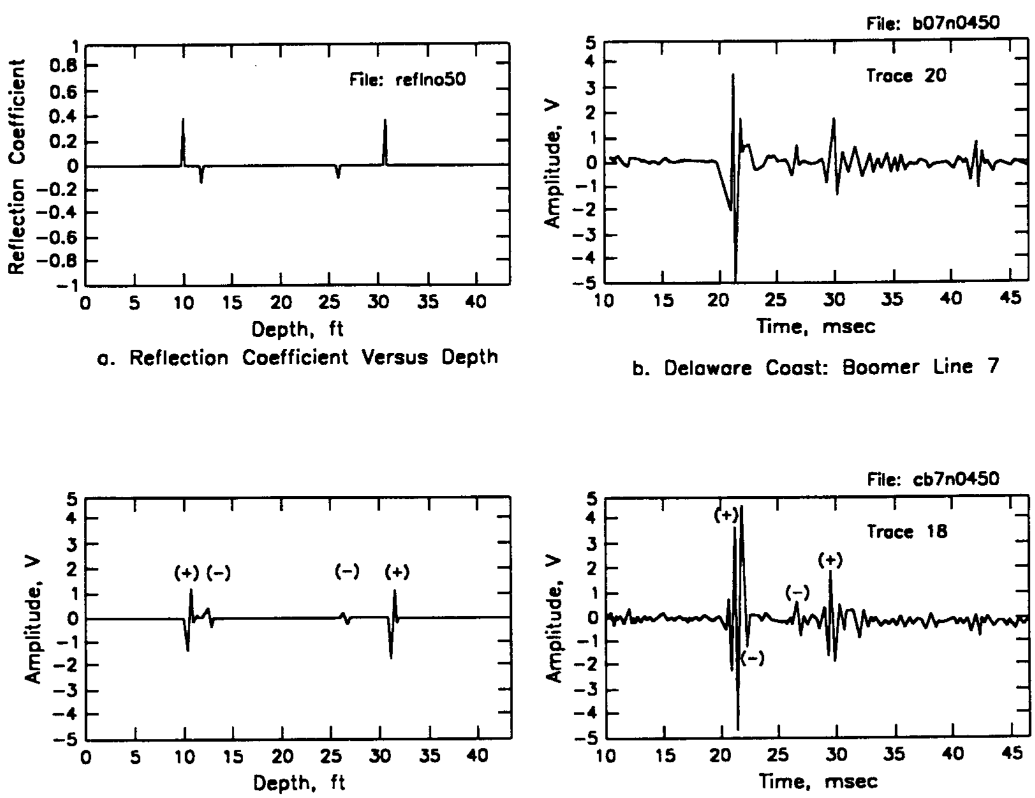
type, and a high-amplitude reflection a significant difference in material. This is not always the case, however, since the absorption and reflectivity of competent sediments will result in apparent high attenuation and a relatively low-amplitude reflection even for a major change in sediment type.

c. *Impedance*. Successive reflectors must exhibit reasonable impedance values. For example, a high-amplitude reflection beneath a packed, poorly graded sand could possibly result in an unreasonable estimate of the impedance if considered to be a positive, or increasing, reflection sequence. On the other hand, this high-amplitude reflector might very well represent a significant change in sediment type, such as silt or clay. Computations of Z based on $\pm R$ values were made throughout the project to assess the reasonableness of successive impedance calculations.

GEOACOUSTIC MODEL - LINE 7
ACOUSTIC PROPERTIES

DEPTH FT	LAYER TYPE	DENSITY g/cc	GRAIN Φ	IMPEDANCE Z	Reflection Coefficient
10	SP	2.1	1.2–0	3400	+0.39
12	SC	1.7	4–2.2	2600	−0.13
26	CL	1.4	>4	2150	−0.09
31	GP	2.5	>0	5000	+0.40

← Core Log Data → ← Acoustic Data →



a. Reflection Coefficient Versus Depth

b. Delaware Coast: Boomer Line 7

c. Delaware Coast: Synthetic Seismogram: b07n

d. Delaware Coast: Boomer–Correlated

Figure 30. Forward model comparison with actual data

Figures 31 through 37 present the remaining geoacoustic calibration summaries of the 3,500-Hz pinger data collected for the Delaware coast survey. Each figure includes a representative section of the reflection data in the vicinity of the core, plots of the acoustically derived estimates of impedance, density, and mean grain size versus depth, measured mean grain size versus depth, and the core lithology. Density predictions are estimated to be within ±10 percent of

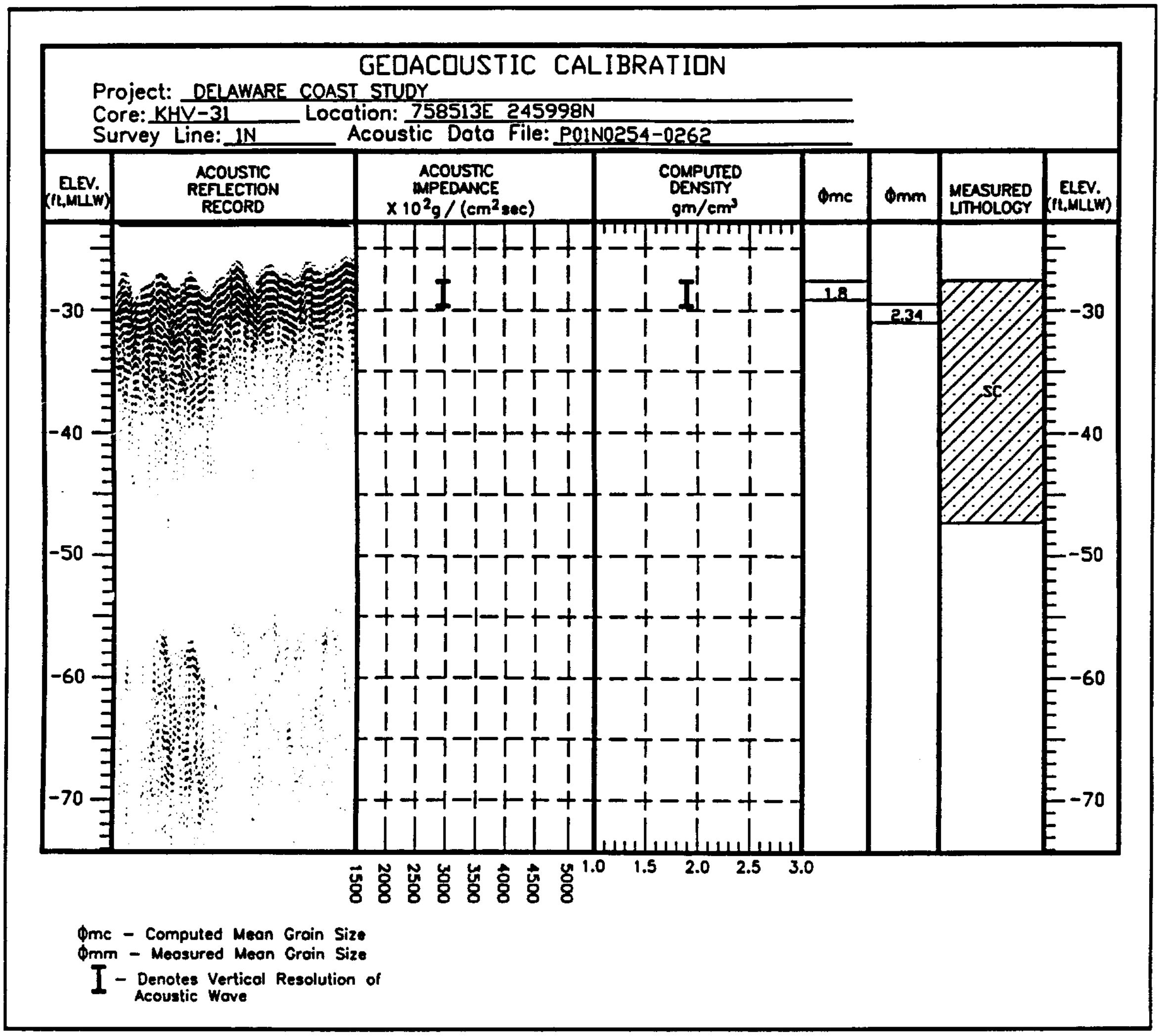


Figure 31. Geoacoustic calibration: KHV-31

in situ since no density measurements were conducted on the core samples. With laboratory density analysis, these results could have been improved to between 5 and 7 percent. Estimates of mean grain size, especially for the surface sediments, are within about ± 0.5ϕ. This is quite encouraging since acoustic response characteristics of sediments as related to mean grain size tend to exhibit more scatter in the data (Chapter 5).

Limitations

As with any remote sensing technique, limitations exist. The limitations must be understood in order to use the method appropriately. Probably the most common fault encountered in geophysical studies is the improper application of a given technique for a given study objective. Following is an overview of the major limitations with the present AI technique as well as project-specific problems.

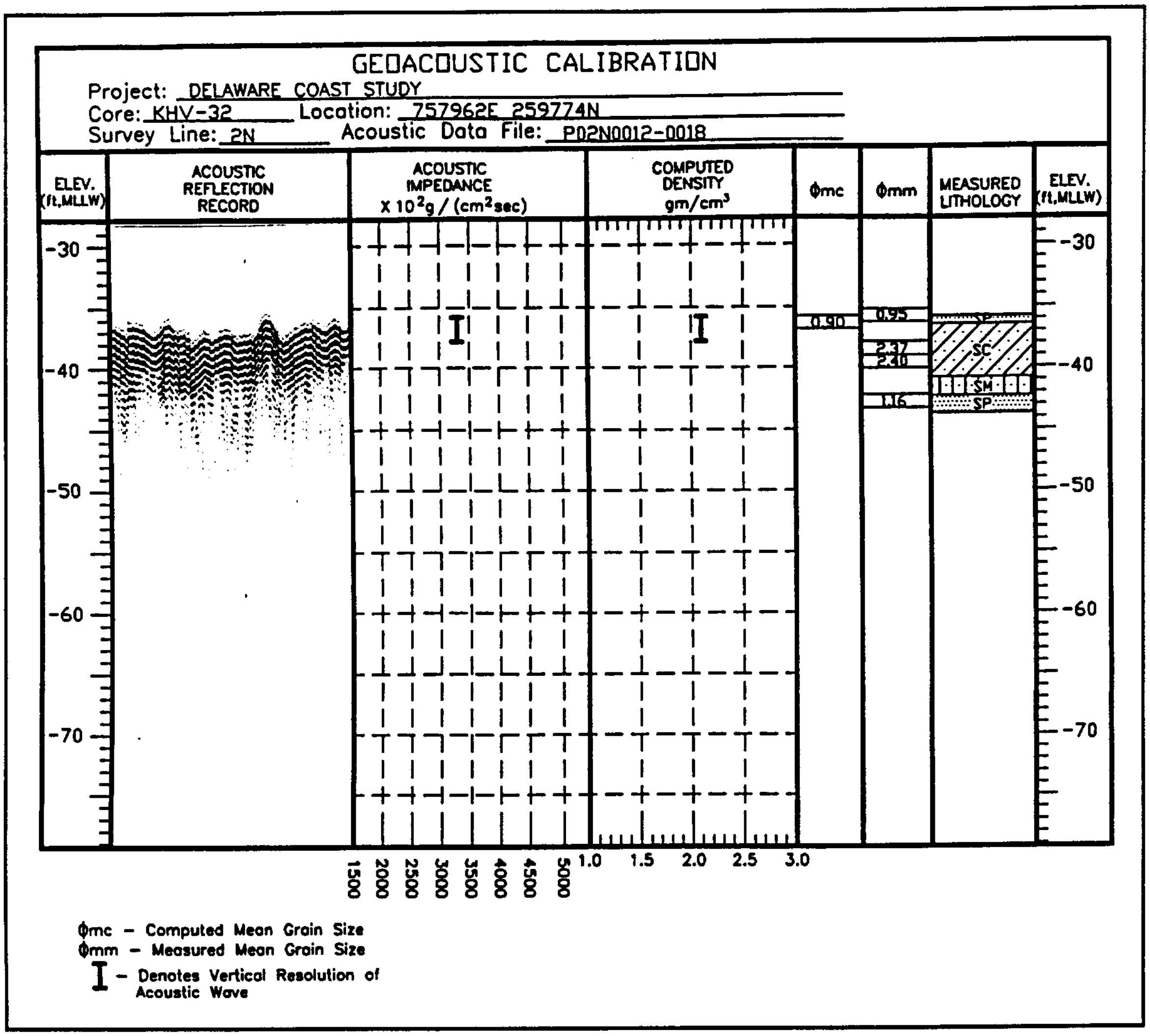


Figure 32. Geoacoustic calibration: KHV-32

Signal-to-noise ratio

The ability to accurately assess any environment is strictly a function of the quality of the data obtained. Low S/N data will produce poor-quality results or possibly no results at all. The AI method limits its processing to data with a S/N ratio greater than 5 db. One must always be suspicious of impedance predictions in areas of poor S/N data. Therefore, no analysis is performed on poor S/N data. The sediment profiles are annotated to identify poor S/N data.

Layer identification

Unique sediment units can be identified only when an impedance change exists. Gradual changes in soil type may not result in an impedance differential large enough to produce a reflection.

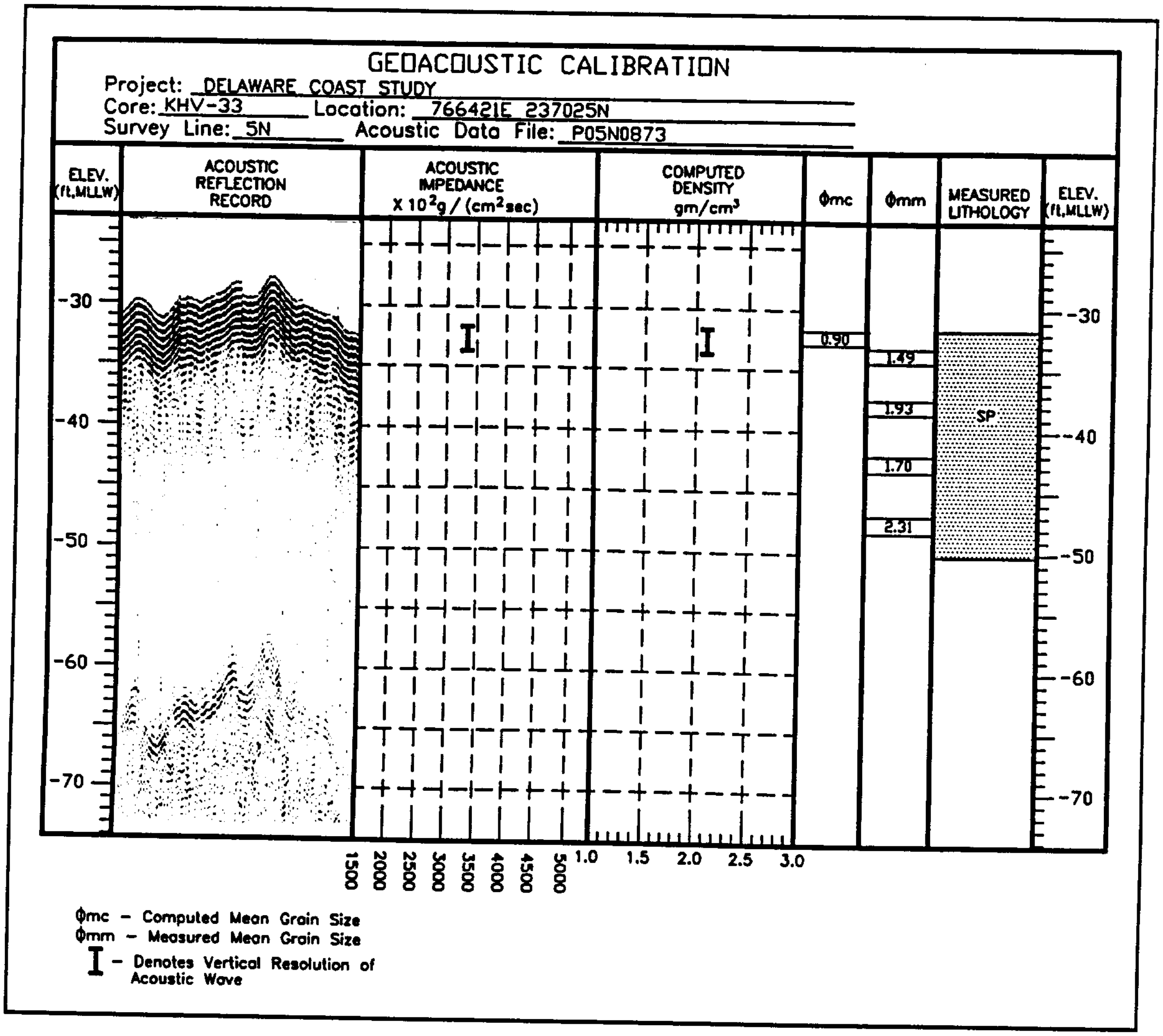


Figure 33. Geoacoustic calibration: KHV-33

Resolution

Vertical resolution and the ultimate depth of penetration are dependent primarily on the frequency of the sound wave. Higher operating frequencies permit greater resolution of the marine sediments but shallower depths of energy penetration depending on the characteristics of the subbottom materials. Also, in high-attenuation sediments, the higher frequencies are attenuated at a higher rate than the low frequencies, resulting in degradation of resolution and errors in absorption estimates for very deep layers. For this study, a pulse length of 1 msec was selected to improve the S/N ratio; however, this limited the vertical resolution to about 2 ft. As stated in the section, "Bathymetry," depths were adjusted to match the high-accuracy fathometer depths, providing 10:1 improvement in the depth resolution.

The greatest effect the 1-msec pulse length had on the data was in the detection of sediment layers of less than 2 ft in thickness. Some of the cores indicated 6-in. to 1-ft layers of sand over silts and clays, and others showed

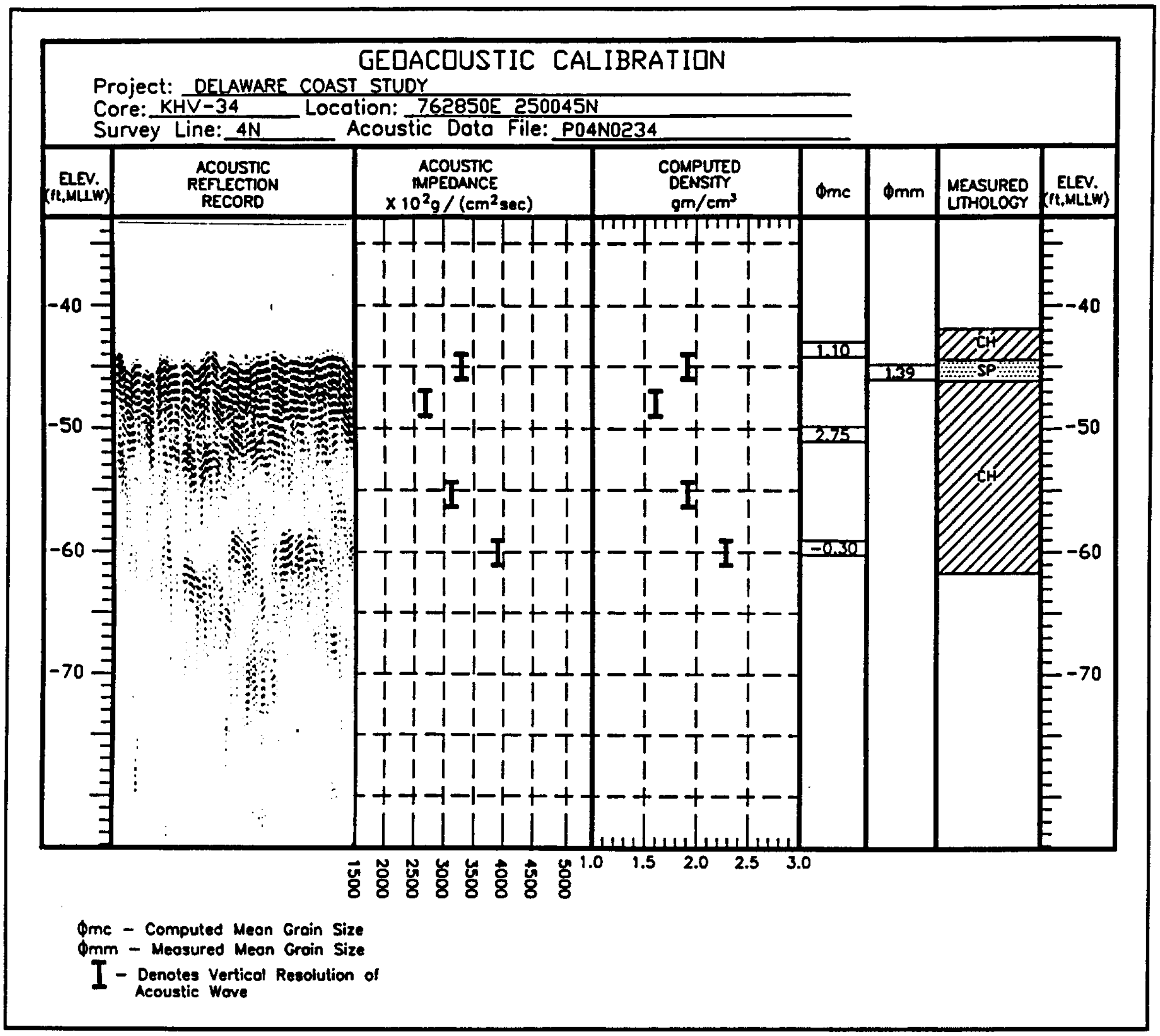


Figure 34. Geoacoustic calibration: KHV-34

lenses of soft sediments between sand layers. Due to the pulse length, these layers are not always detected. Cores KHV-32, KHV-34, and KHV-39 are examples of both of the situations and are presented, along with the acoustic profile data, in Figures 32, 34, and 29, respectively. In order to overcome this problem, individual pings, or data traces, were analyzed to identify vertical changes in the sediment structure. Figure 38 shows a section of the subbottom reflection record for line P05N in the vicinity of core KHV-36 and a sequence of selected individual data traces for the same record. Reflections are occurring close together and multiple layers are not always readily apparent on the subbottom record. This can also cause problems in analytically detecting each reflection horizon, requiring more detailed analysis as shown in Figure 38 to properly assess the sediment environment. Should a significant change of material occur within the pulse length of the echo wavelet, detection may not occur.

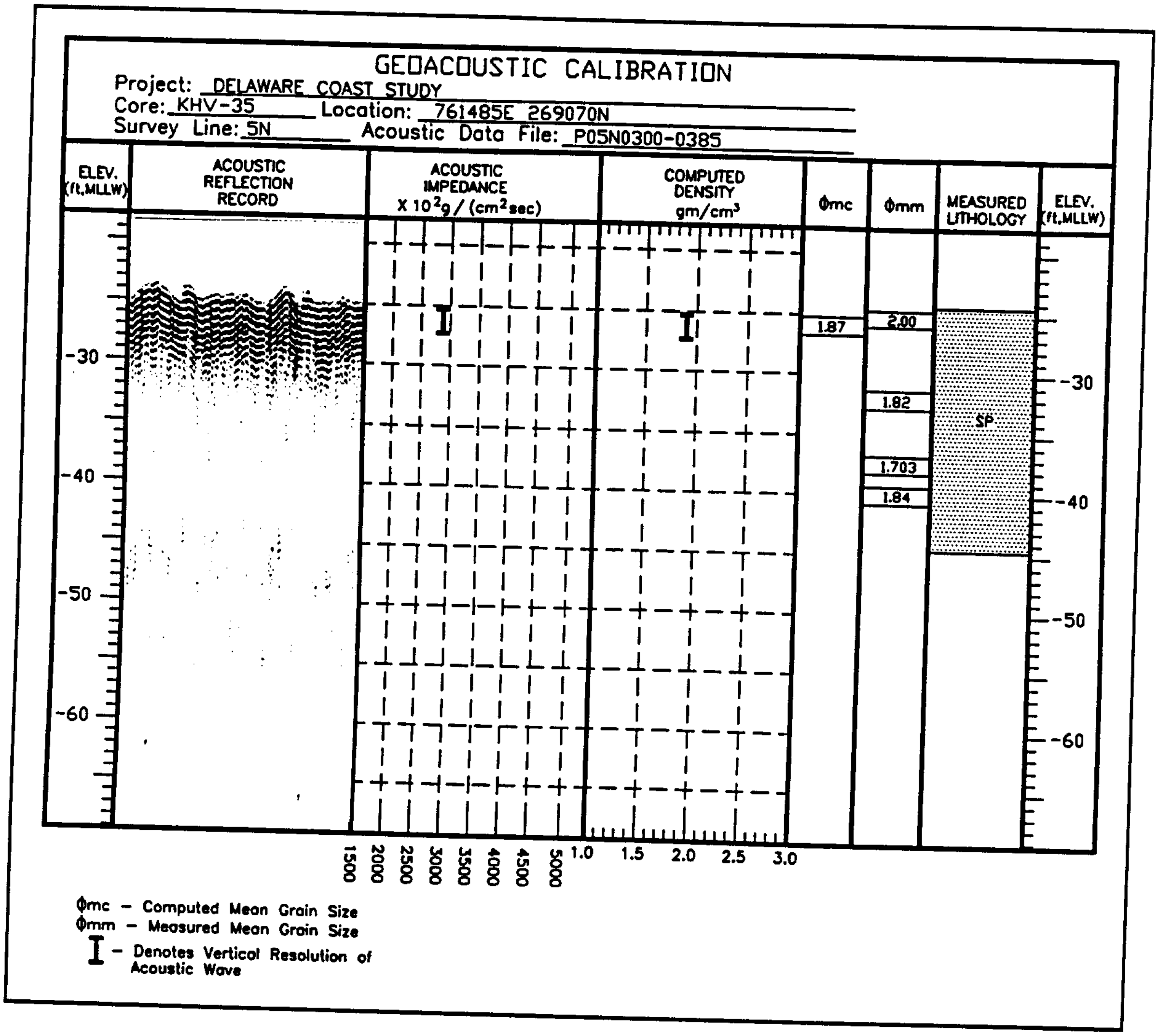


Figure 35. Geoacoustic calibration: KHV-35

Beam pattern or directivity

Experience has shown that beam pattern and transducer directivity contribute significantly to signal degradation. Sloping bottoms and rapidly dipping reflection horizons cause inconsistent reflection data through focusing and defocusing of the incident energy. Rough, irregular bottoms with numerous scatterers will specularly disperse energy away from the receiving array. Specific directivity problems and the approach to solving the problem are discussed in the section, "Equipment Calibration: Sources and Receivers."

Relatively shallow cores

Cores were collected to depths of 20 ft below the bottom. Since the objective of the study was to identify sediments in the uppermost 20 ft of the subsurface, the core depths would seem to be sufficient. In general, they are; however, in some areas of the study, significant subsurface anomalies and

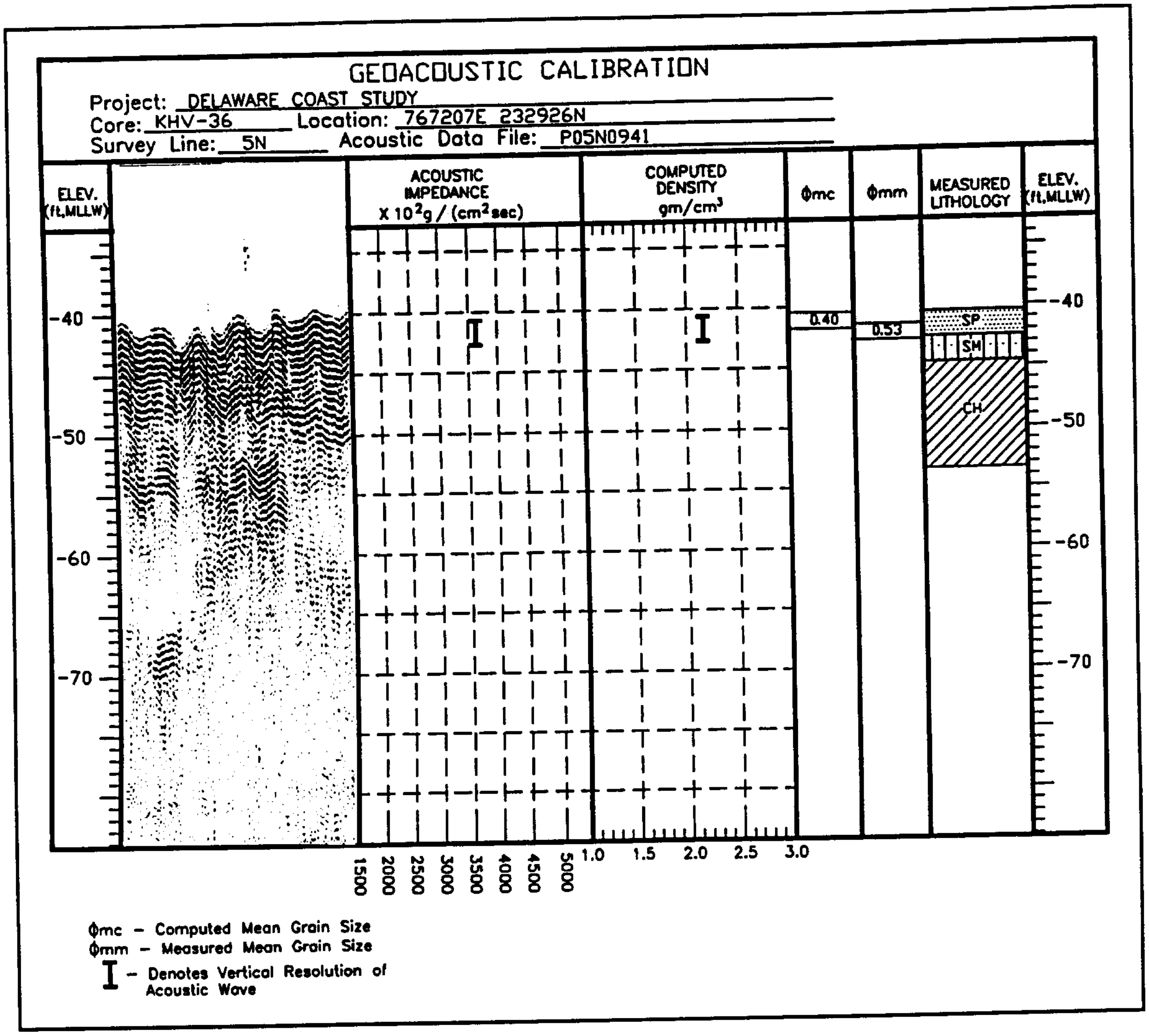


Figure 36. Geoacoustic calibration: KHV-36

noncomformities were detected below the 20-ft depth, preventing absolute verification of the acoustically derived sediment properties.

Sediment sample density measurements

As stated in Chapter 5, no density measurements were obtained on any of the samples taken from sediment cores. Even though density measurements from vibracore samples are not considered absolute measures of in situ density, they do provide reasonable estimates of the overall competency of the sediments in question. The standard error associated with the acoustically derived density estimates could have been reduced to ± 5.0 percent compared with the ± 10.0 percent determined for this study. It is highly recommended that laboratory determinations of wet density be obtained on all sediment samples for AI studies.

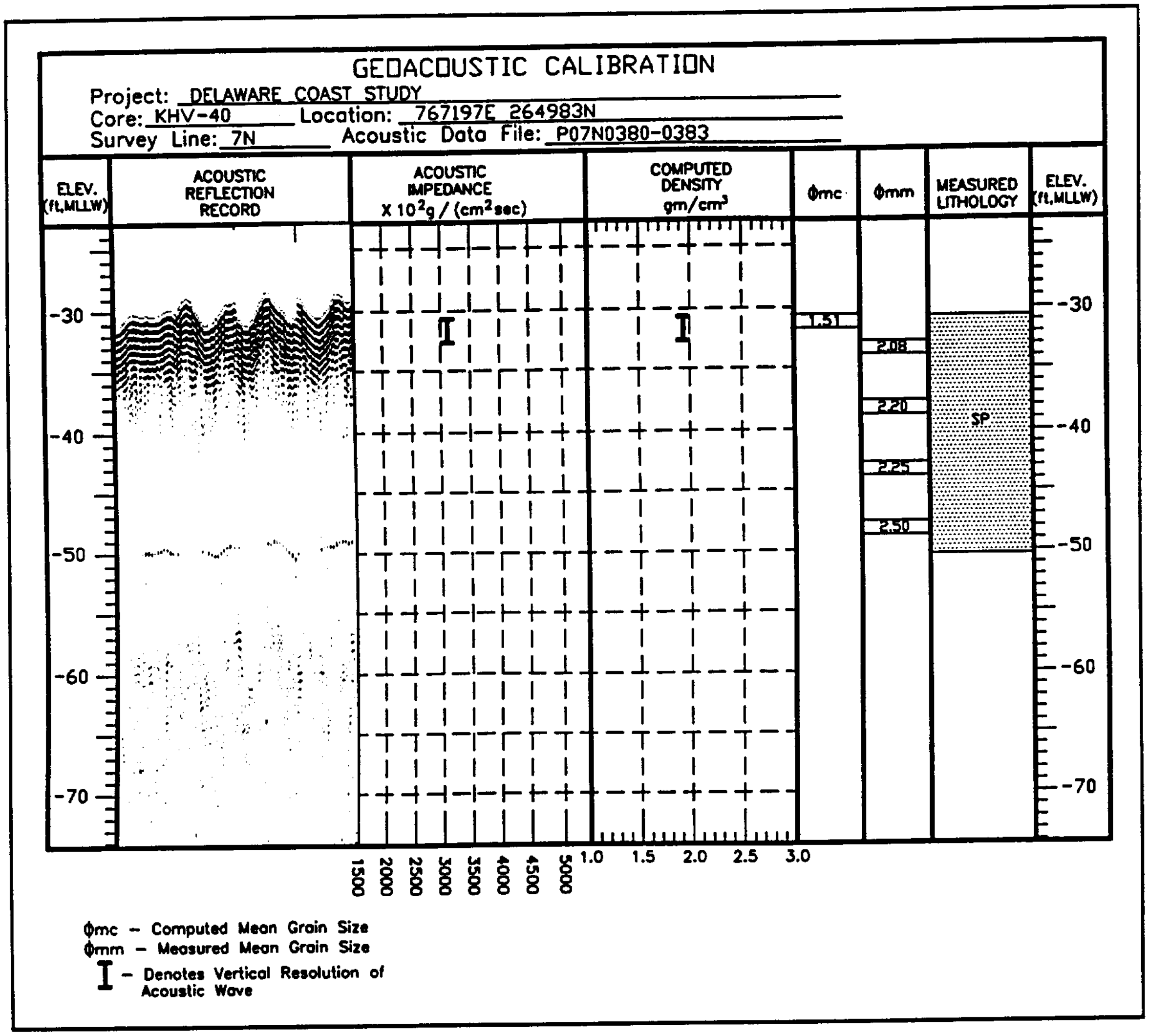


Figure 37. Geoacoustic calibration: KHV-40

Frequency

The "Absorption calibration" section describes a technique for assessing absorption by comparing the rate of absorption in a given sediment across a range of frequencies. Two frequencies were operated during the survey, 3,500-Hz pinger and 1,000-Hz boomer sources. In the presence of competent sands and gravels, acoustic penetration was severely limited with the pinger source, preventing detection of material changes within the upper 20 ft of sediment. The boomer source, operated for the purpose of penetrating through these competent layers, did not always deliver data of sufficient S/N ratio useful for analysis. Sea conditions during the time of the survey precluded the optimum operation of the boomer. The only boomer data collected that provided any analytical benefit was along line 7N and was used for the absorption calibration. Because the pinger was the only reliable data source, acoustic penetration is limited in some areas.

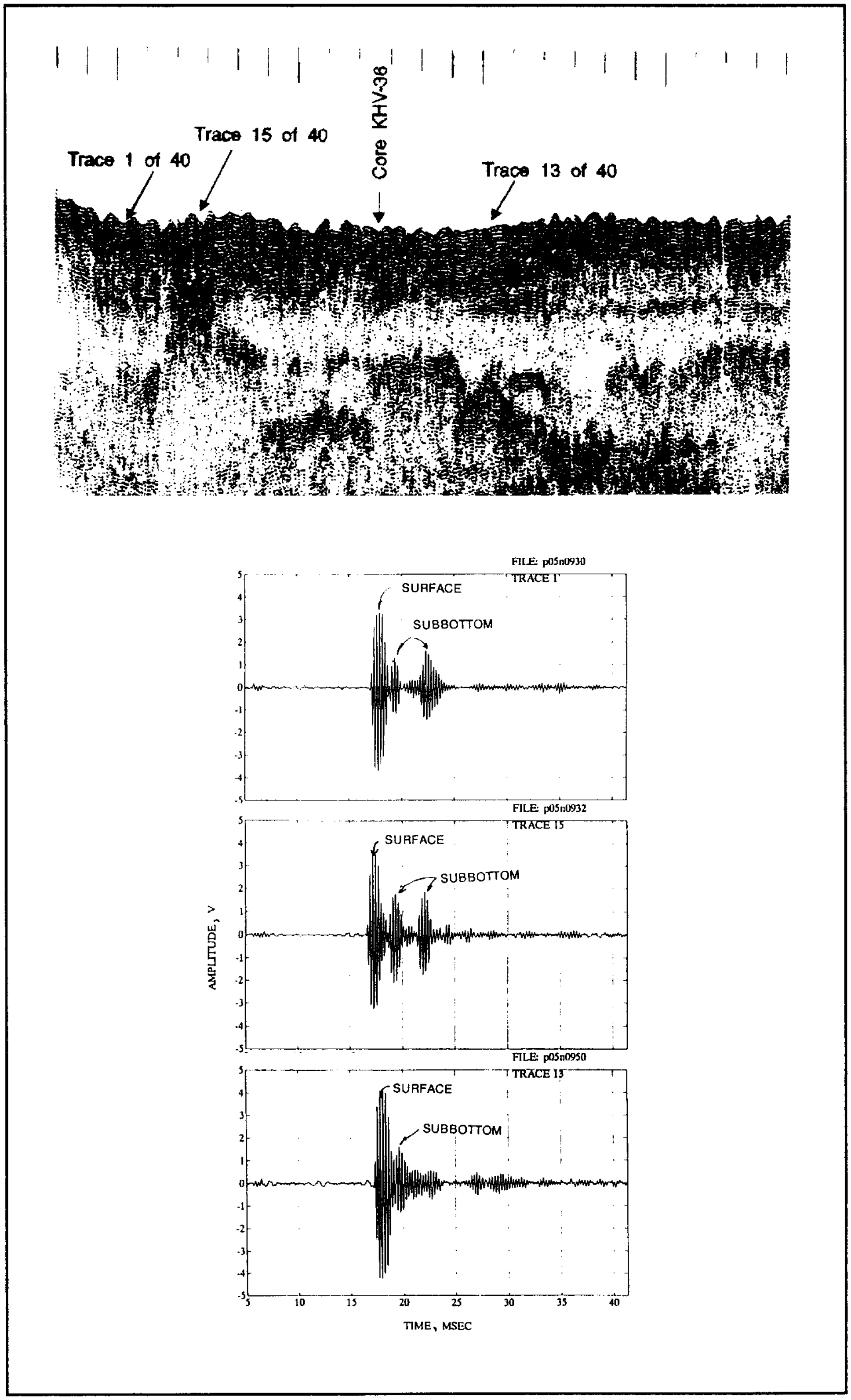


Figure 38. Subbottom record from line 5N and individual time-histories

7 Phase V: Discussion of Results

Sediment Profiles

The distributions of computed sediment densities and mean grain sizes within the project area are presented in Plates 1-41 as two-dimensional profiles illustrating the primary bottom and subbottom interfaces and differing zones of sediment material. For presentation, the survey area is divided into four equidistant zones, two in the north sector and two in the south (Figure 6). The naming convention for the plates identifies the general vicinity of each line; i.e., line P10N-N is the sediment profile for the northern half of line 10N. The profiles illustrate the depth to a particular interface (in feet mllw), representative sediment properties, and corresponding location along the survey line. The labelled black dots at the top of each profile denote the survey track line and direction. Each dot also represents the beginning of every seismic data file recorded in order to give an indication of the data coverage along each line and assist in correlating the raw data and interpreted results. The associated label represents the data file number and correlates with the data file number on the color subbottom reflection records (Figure 8). Lines of latitude are displayed on each profile. The sediment profiles have been completely adjusted for horizontal position (effects of boat speed) and survey heading. All profiles are presented heading in a southerly direction, allowing consistency in the data interpretation. Actual boat heading is in the direction of increasing data file numbers on the profiles. Finally, all cores used during the study are identified on the profiles.

Sediment Description

The sediments encountered in the survey area off the Delaware coast consist primarily of marine sands of varying gradations, ranging from muddy, silty sands to poorly graded sands and gravels. The study correlates very well with the findings of Sheridan, Dill, and Kraft (1974) and Collins (1982). Figure 39 presents areas within the survey recommended for further testing as to their suitability as sources of potential beach replenishment material.

Northern sector summary

The northern sector of the survey comprises three basic physiographic units: (a) the Hen and Chicken Shoal complex in the northern half, (b) a shelf-transverse valley to the south of the Hen and Chickens Shoal, and (3) a linear shoal field located directly east of Rehoboth Bay. Plates 1-21 present the sediment profiles for the northern sector of the study area.

The Hen and Chickens Shoal is located off of Rehoboth Beach between 280,000N and 255,000N as shown by the contours in Figure 9. Sediment profiles for the shoal are presented in Plates 4-10 and 20 and 21. Five cores, KHV-35, -37, -40, -41, and -58 (Appendix A), were located within the Hen and Chickens Shoal. These cores described poorly graded fine to medium sands, with the coarser materials located on the eastern half of the shoal. The acoustic analysis correlated very well with the core analysis. Figures 40 and 41 present acoustic *BL* and *Z* computations, computed density, and mean grain size for the surface sediments near core locations KHV-35 and KHV-40 (Figures 35 and 37). These computations are based on the geoacoustic models of Figures 20 and 21. No subsurface reflections were detected along the crest of the shoal, supporting the core data showing uniform sediment characteristics for the full depth of core (20 ft). The core and acoustic data show the sediments along the Hen and Chickens Shoal, designated as area A in Figure 39, as a potential sand source.

A shelf-transverse valley is depicted south of the Hen and Chickens Shoal directly east of Rehoboth Bay between 255,000N and 240,000N. The acoustic data revealed a competent reflector at depths of up to -90 ft extending to the surface near 255,000N to the north and 237,000N to the south. This reflection horizon has been identified by Sheridan, Dill and Kraft (1974) as a pre-Holocene surface forming a valley filled with lagoonal muds, silts, and clays (Plates 16-21). Numerous paleochannels filled with these materials were detected near shore developing into two major paleochannels in the vicinity of line 5N. These paleochannels correspond to the ancient drainage systems identified by Kraft in Figure 2. The reflecting facies within these channels tend to be parallel, indicative of low-energy flood-type inundations, such as the sea level rise of the recent Holocene era. This Holocene sediment environment is described in some detail by Sheridan, Dill and Kraft (1974). Figure 42 is a geologic cross section of the central Rehoboth Bay area developed by Kraft (1971). This cross section runs transverse to the longitudinal profile lines surveyed for this study. This figure shows the estimated intersection points of each survey with the geologic cross section. This cross section confirms the acoustic results. The ancient Pleistocene headlands depicted correspond with sediments characterized as coarse sands and gravels on the southern end of lines 10N and 11N (Plates 20 and 21, respectively).

Several cores in the central Rehoboth area revealed near-surface sediments classified as clayey sands (SC), with other cores containing poorly graded medium sands in the top 6-12 in. The associated acoustic *BL* measured in these areas predicts sediment densities greater than 2.0 g/cm^3 and mean grain

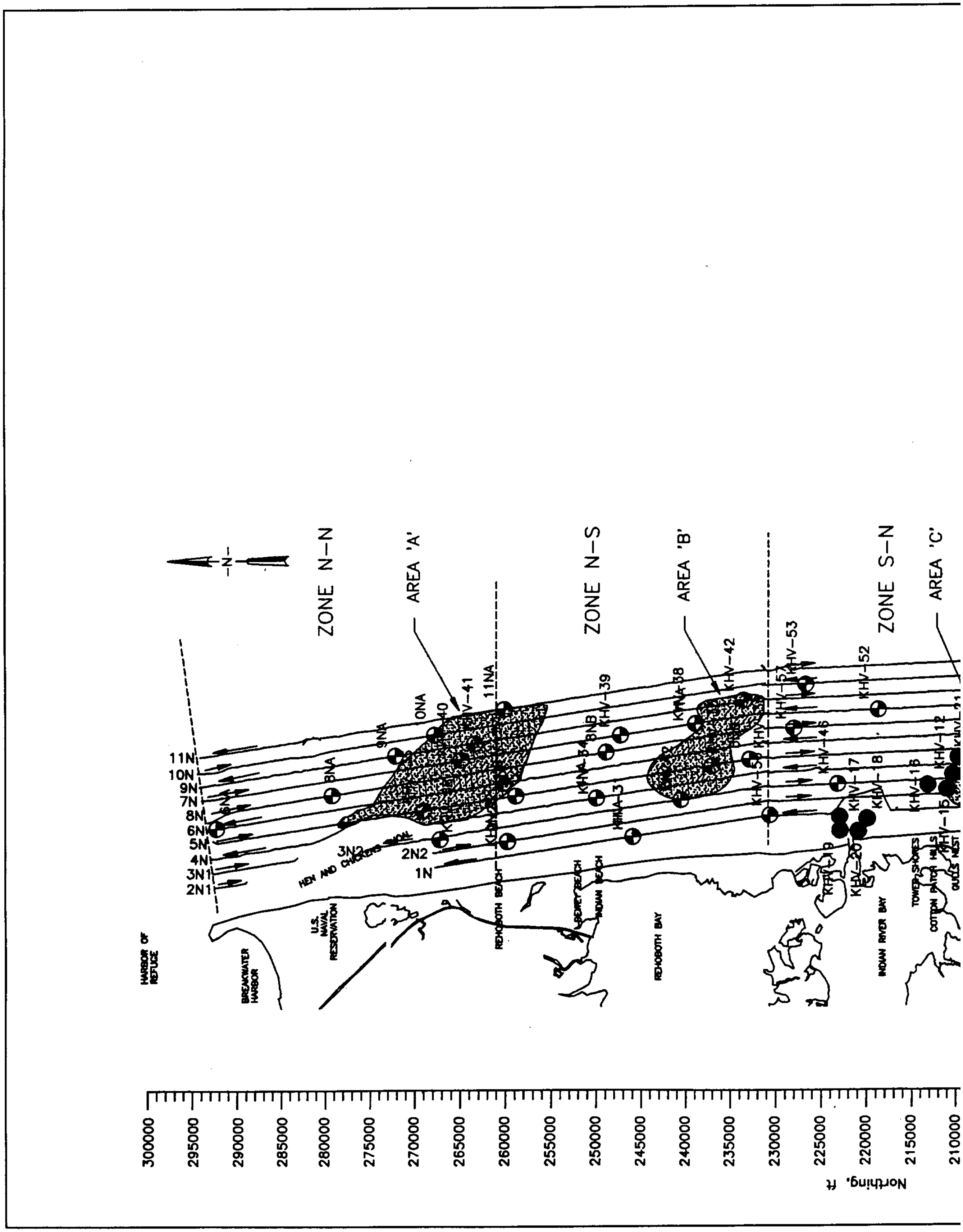
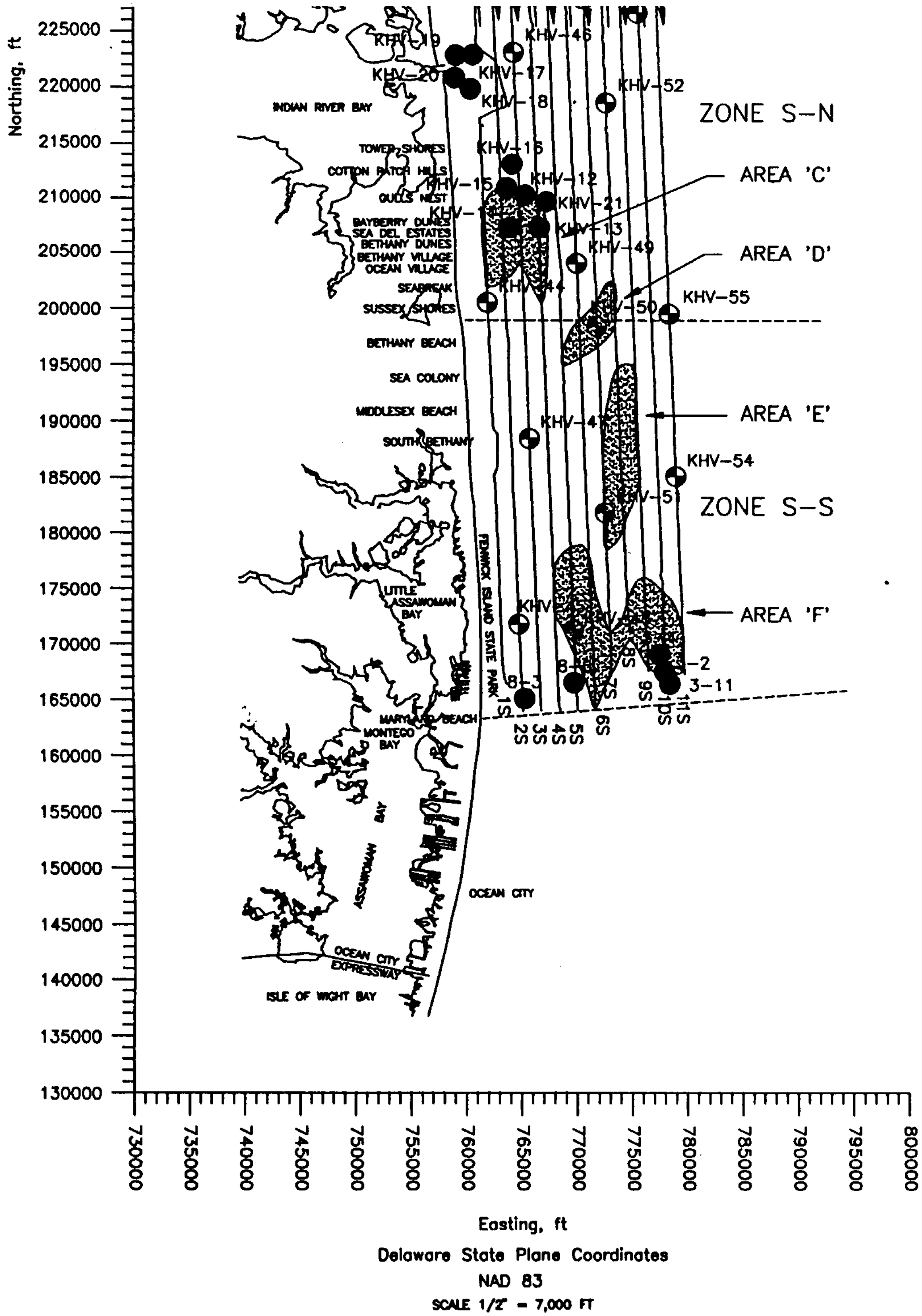


Figure 39. Potential borrow areas



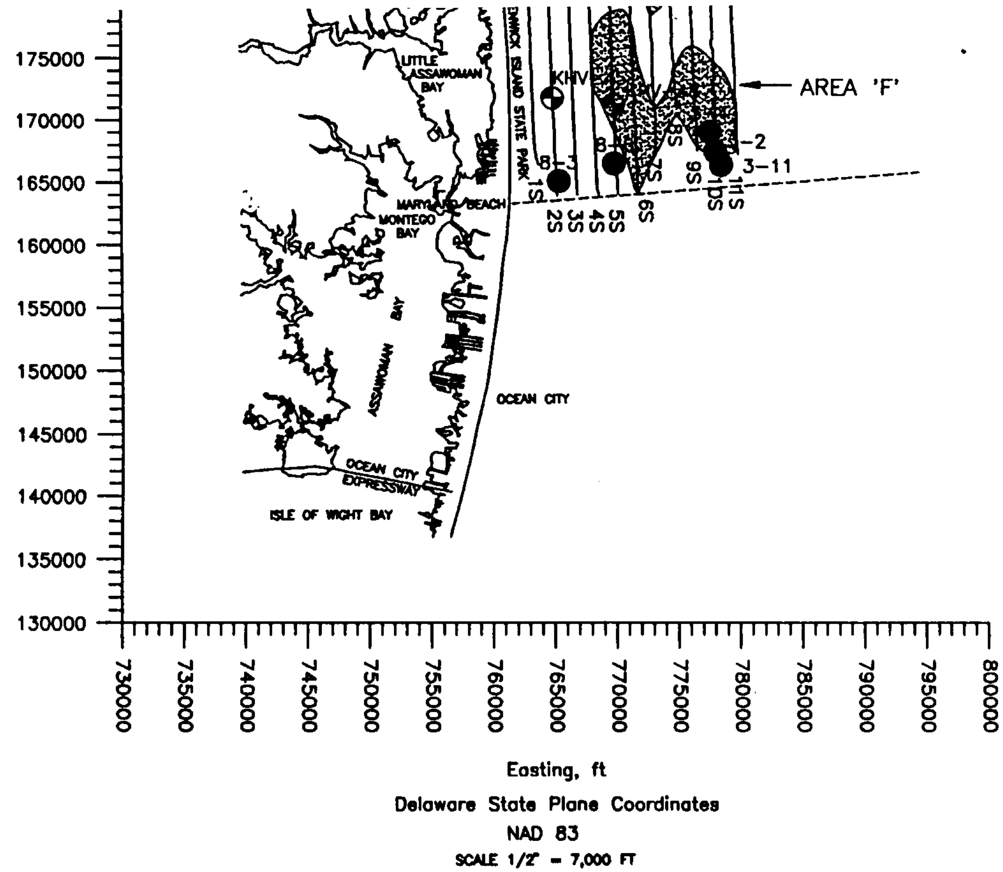
LEGEND

- Existing Core Location
- 1993 Core Location
- Areal Extent of Granular Sediments (No Fines)

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS

DELAWARE COAST
ACOUSTIC SUBBOTTOM SURVEY

DATED 15 August 1995	Survey Lines and Core Locations



LEGEND

- Existing Core Location
- 1993 Core Location
- Areal Extent of Granular Sediments (No Fines)

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS

DELAWARE COAST
ACOUSTIC SUBBOTTOM SURVEY

DATED	
15 August 1995	Survey Lines and Core Locations

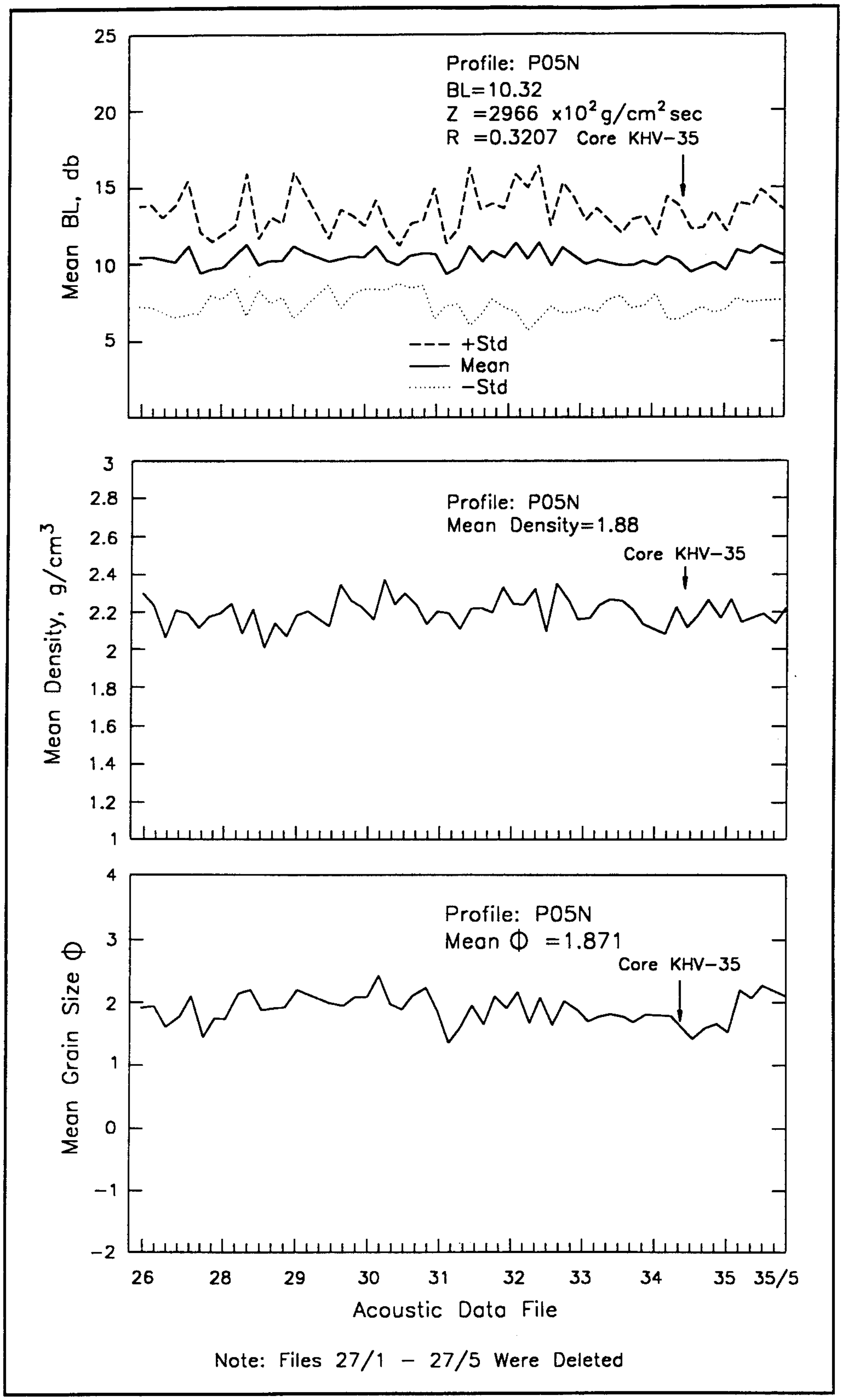


Figure 40. Acoustic surface analysis for core KHV-35 area

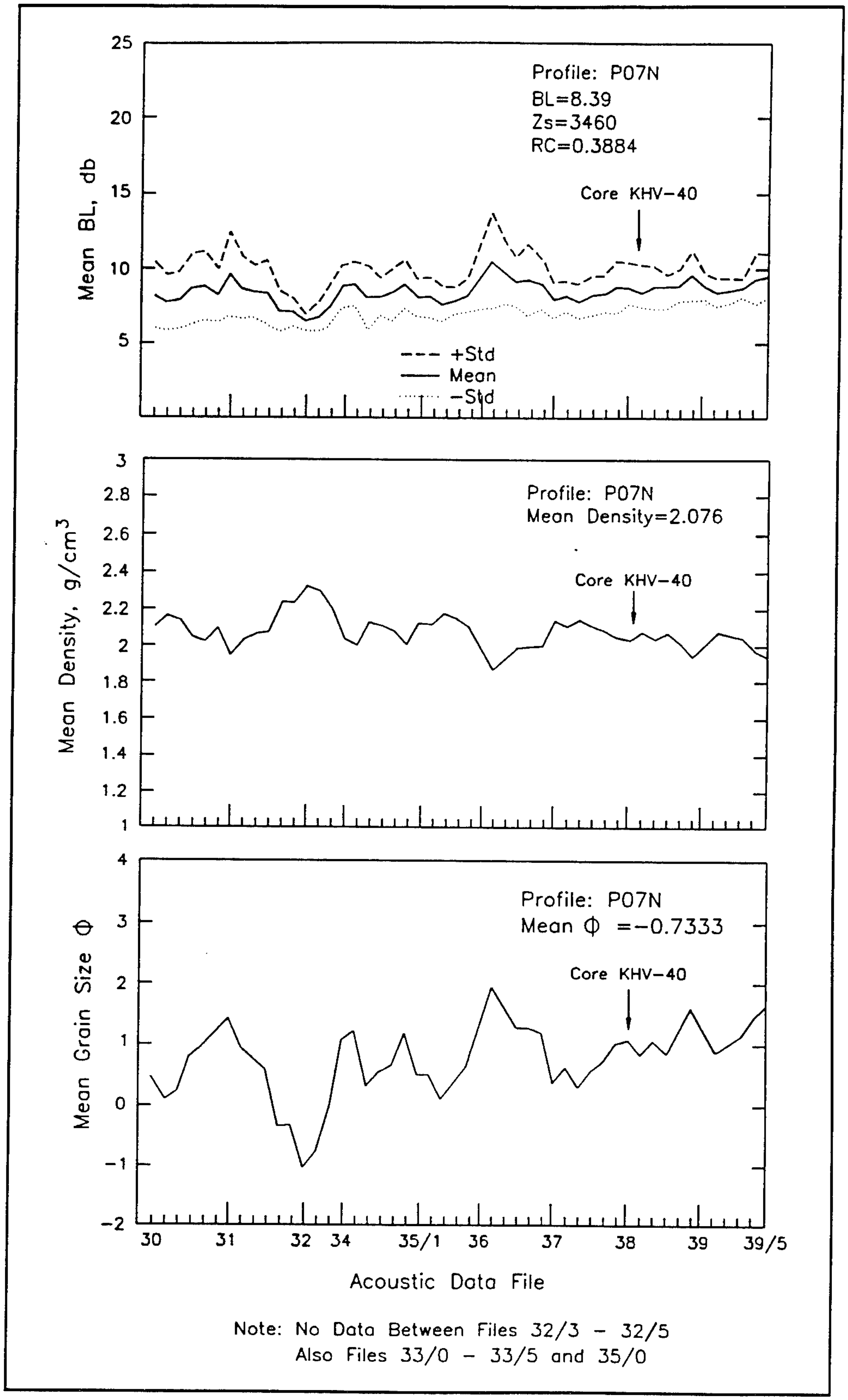


Figure 41. Acoustic surface analysis for core KHV-40 area

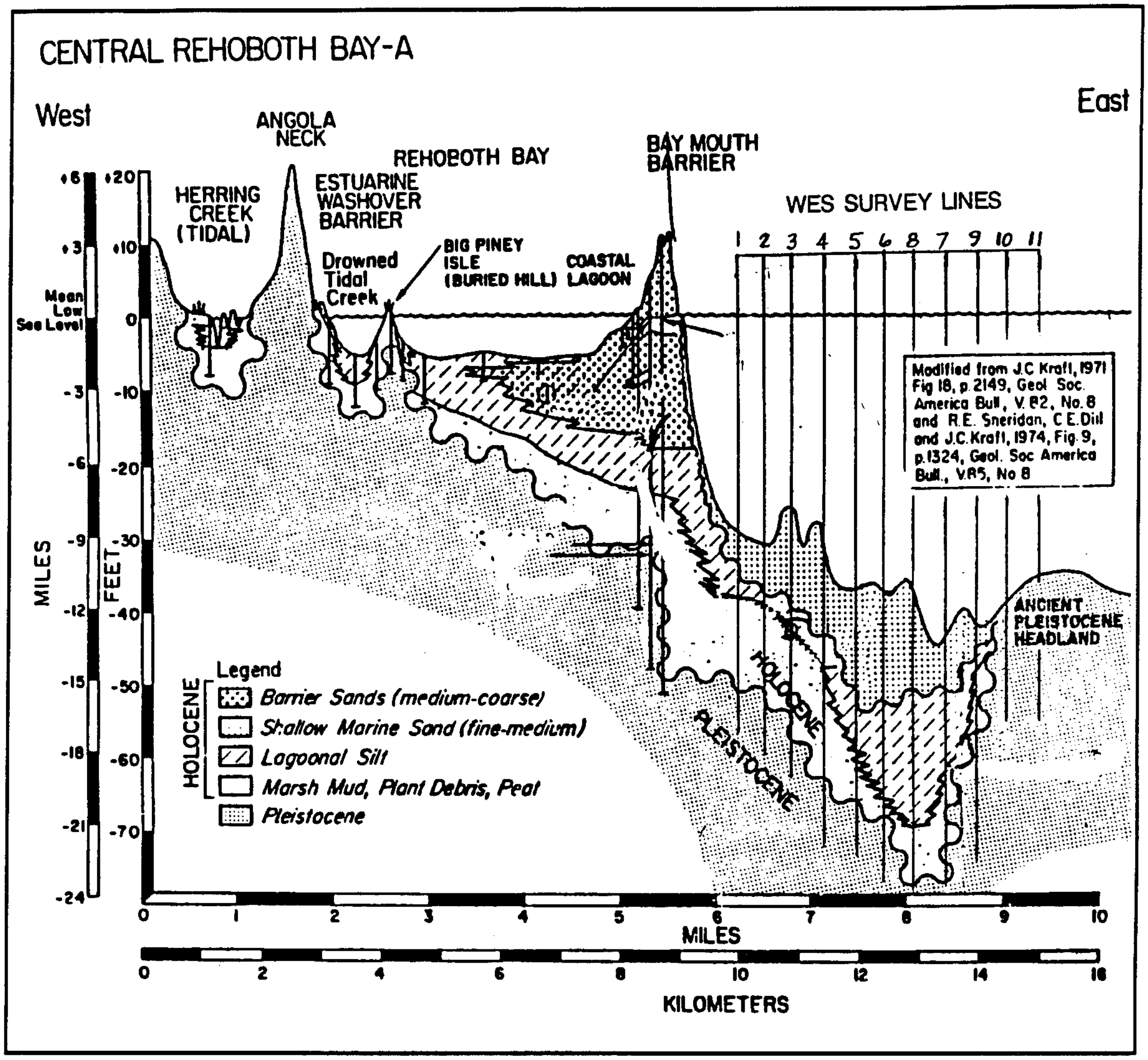


Figure 42. Geologic cross section: Central Rehoboth Bay modified from Collins (1982). WES survey lines added by author

sizes ranging between -1ϕ and 1ϕ. Core KHV-39, described as an SC, contains 7 percent gravel, 82 percent sand, and 11 percent fines, with a ϕ_m equal to -0.019, explaining the acoustic response. Figure 43, the acoustic surface analysis for Core KHV-39, shows a computed mean grain size of -0.18ϕ. Sheridan, Dill and Kraft (1974) described these sands as "not reminiscent in structure or sorting of beach and dune sands; rather they exhibited properties of reworking as if they were part of the dynamic bed form in equilibrium with the present nearshore marine environment." Philadelphia District cores and the acoustic analysis correlate with this assessment. The surface materials contain quantities of very coarse grained sediments laced with 10-20 percent fine materials. The sediments in this area are not considered suitable for beach replenishment purposes.

A linear shoal field located between 245,000N and 230,000N along lines 3N through 9N contains fine to medium sands possibly suitable for beach material. This area is denoted as area B in Figure 39 (Plates 13-19). Core

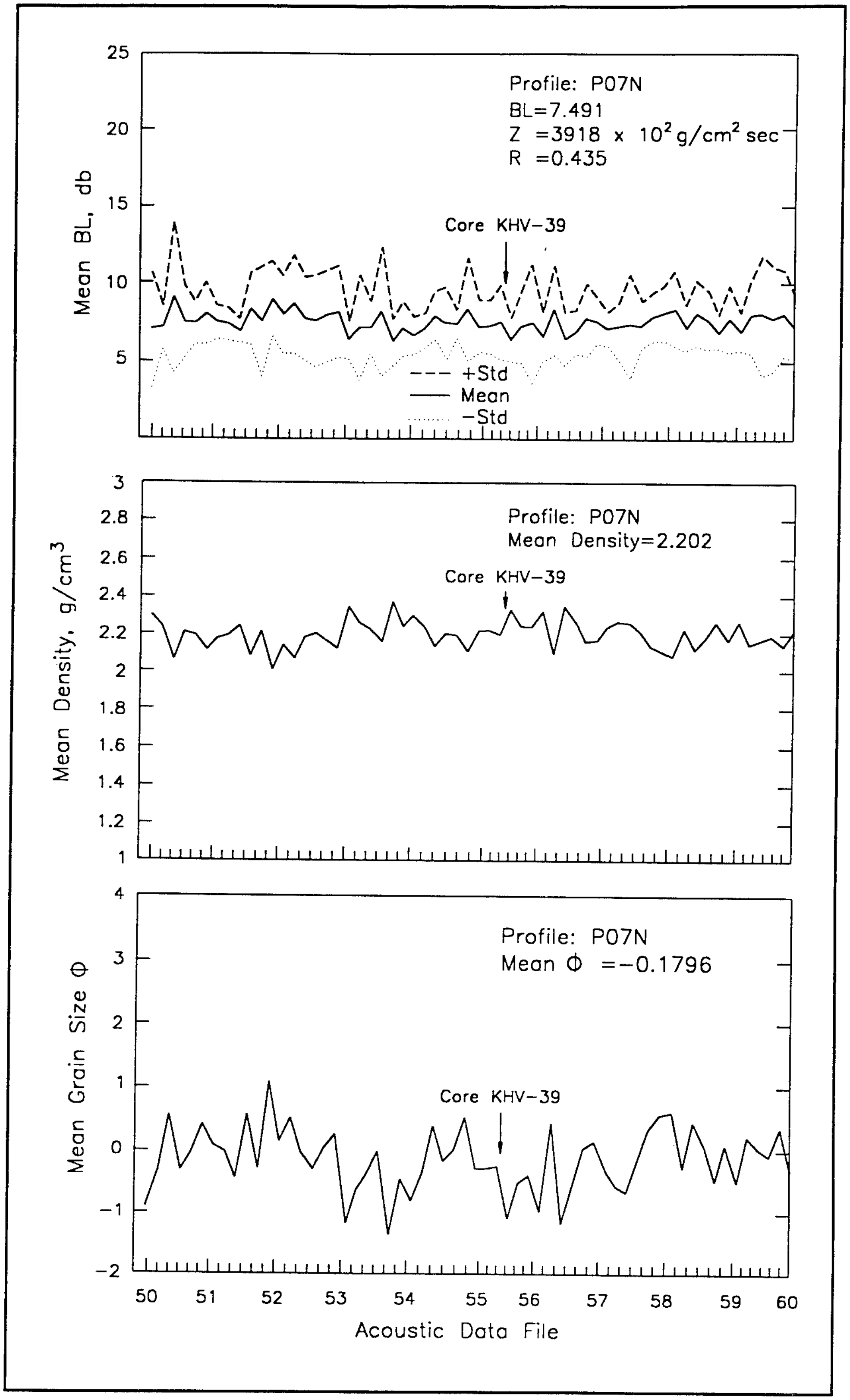


Figure 43. Acoustic surface analysis for Core KHV-39 area

KHV-33 revealed poorly graded sand with a mean grain size of 1.49ϕ at the surface, becoming finer with depth. The acoustic results indicated a mean grain size of 0.90ϕ. Sediment thicknesses in this area range between 5 ft at the edges of the area to 20 ft near the center. Core KHV-2, near the outer edge, shows 4 ft of sand over clay, corresponding precisely with the acoustic data. More detailed analysis, either through coring or additional subbottom profiling, is required to delineate the limits of material in this area.

Southern sector summary

Two primary physiographic features found in the southern sector are (a) linear shoal fields and (b) shoal-retreat massifs. Also, three paleochannels transversing the survey area were detected within the southern sector. The northernmost feature corresponds to the Indian River Inlet (Figure 39) and is located between 230,000N and 225,000N (Plates 22-31). The submarine sediments in the channel consist primarily of clays and clayey sands. Core KHV-46 punctures the edge of this paleochannel along line 3S (Plate 24) and describes dark grey muddy sand overlying silty clays and muddy fine sands. The sediment unit identified by the deepest reflector consists of well-graded coarse sands. The second paleochannel transverses the survey area in a northeast heading. It was first detected near Bethany Beach at 195,000N (Plate 32). This channel can be tracked on the sediment profiles in the northern section of Plates 32-35, and the southern section of Plates 27-31. The sediments filling this channel are similar to those found in the Indian River paleochannel. A third less defined relic channel transverses all survey lines in the southern sector between 180,000N and 175,000N (Plates 32-41). The acoustic analysis revealed a reworked muddy sand overlying clayey sands. No sediments in these areas are considered suitable for further testing for beach replenishment sources.

A significant shoal field is located north of Bethany Beach between 211,000N and 200,000N along lines 1S through 4S. This area is shown in Figure 39 as area C and is described in the sediment profiles in Plates 22-25. The acoustic and core data show fine to medium poorly graded sands overlying clays and clayey sands. Sand thicknesses range between 3 and 15 ft.

Areas D and E in Figure 39 are described as shoal-retreat massifs surrounded by reworked clayey sands of the paleochannels in the southern sector. Core KHV-50 centered along the crest of area D shows 1 ft of grey stiff mud (CL) at the surface that was undetected by the acoustic data. The remainder of the core consisted of medium to coarse poorly graded sand. The acoustic computations showed fine sand overlying medium sand. Additional cores and possibly different acoustic data are required to confirm the horizontal extent of the surface clays shown in the core log.

A large shoal-massif at the southernmost end of the study area, labelled area F in Figure 39, is situated along survey lines 4S through 11S between 180,000N and 165,000N (Plates 35-41). The sediments in the southern half of this area have been previously evaluated as beach replenishment material for Ocean City, MD (Anders and Hansen 1990). Core KHV-48 located along 5S in

area F showed 4.5 ft of well-graded medium to coarse sand to el -55. The acoustic data support the core information as shown in Plate 36. The acoustic analysis over the remainder of the shoal indicated primarily fine to medium sands with no fines. Although acoustic penetration is limited in this area due to high acoustic attenuation, a layer of clayey sands may underlie the shoal at about el -60. This is based on the acoustic reflection data from the seabed sediments surrounding the shoal.

8 Conclusions and Recommendations

A comprehensive subsurface exploration program has been accomplished to establish possible limits of available granular materials for potential borrow areas for use as sources for beach fill. This being a reconnaissance-level investigation, the results are not intended to assess the suitability of any marine sediment as beach quality material; rather, the results are intended to pinpoint areas for further detailed investigation. Analysis of 3,500-Hz and 1,000-Hz seismic reflection data in conjunction with vibracore sampling data from selected sites throughout the Delaware coast study area has been completed. The seismic data were correlated with the laboratory analysis of the sample data through acoustic impedance analysis. The sediment characterization is presented as sediment profiles (Plates 1-41) presenting the major reflection facies with descriptions of the engineering properties, i.e., wet density, mean grain size, and associated soil types.

The Delaware coast sediment characterization developed to relate density, mean grain size, and soil type is provided in Table 3 delineating the predominantly clay, silt, and sand sediment types. No laboratory measurements of density were available for any of the cores used for this study. Therefore, in situ density was empirically inferred from mean grain size versus density relationships developed from several project databases (Figure 12), resulting in acoustically derived density values estimated to be within ± 10 percent of in situ. Density predictions could have been improved to better than ± 5.0 percent had density been directly measured. Acoustically derived values of mean grain size are estimated to be within ± 0.5 ϕ.

Six areas labelled A through F in Figure 39 were identified as containing sediments potentially suitable for further analysis as beachfill. In the northern sector of the study is found the largest area (area A) of potential beach sediments, along the Hen and Chickens Shoal. The core data and the acoustic data described mostly poorly graded fine to medium sands, with the coarser material located on the eastern half of the shoal. Sand thicknesses are in excess of 20 ft in some areas. Area B is a linear shoal field containing fine to medium sands located in the middle of the study area directly east of Rehoboth Bay. Sand thicknesses range between 5 ft near the edges of the area to 20 ft near the center. The remaining areas are located in the southern sector south of Indian River

Inlet. Area C, located just north of Bethany Beach, is an area described as fine to medium poorly graded sands overlying clays and clayey sands. Sand thicknesses range between 3 and 15 ft. Areas D and E are linear shoals located approximately 4 miles offshore consisting of fine to medium poorly graded sands. Stiff mud present at the top of core KHV-50, centered along the crest of area D, was undetected by the acoustic data. The final area (area F) is a large shoal-massif situated over the southernmost 3 miles of the study area just north of Ocean City, MD. Fine to coarse sands with little or no fines are distributed throughout the area. The bottom boundary of this shoal complex lies between -55 and -60 ft mllw providing up to 15 ft of material thickness.

The AI method attempts to estimate the engineering properties of bottom and subbottom marine sediments in a quantitative fashion. Whenever an assumption was made based on something other than mathematical processing, that assumption was stated. Also, whenever the data were not sufficiently high in S/N ratio, no attempt at interpretation was made, except as verified by core data. Totally subjective interpretations were strictly avoided.

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Table 1
Delaware Coast Geoacoustic Survey Core Locations

Core Name	Location		Date Collected
	Easting	Northing	
KHV-2	762648.16E	240574.95N	
KHV-12	765453.24E	210350.58N	2 May 84
KHV-13	766756.25E	207353.51N	2 May 84
KHV-14	763955.21E	207324.52N	2 May 84
KHV-15	763770.21E	211026.60N	2 May 84
KHV-16	764262.22E	213179.64N	2 May 84
KHV-17	760705.18E	222985.86N	2 May 84
KHV-18	760482.17E	219961.80N	2 May 84
KHV-19	759172.15E	222944.87N	28 April 84
KHV-20	759059.15E	220945.83N	29 April 84
KHV-21	767372.27E	209752.56N	2 May 84
KHV-31	758513.04E	245998.51N	7 June 93
KHV-32	757962.03E	259773.78N	7 June 93
KHV-33	766421.10E	237024.90N	9 June 93
KHV-34	762849.96E	250044.53N	7 June 93
KHV-35	761484.85E	269070.42N	8 June 93
KHV-36	767206.80E	232926.30N	10 June 93
KHV-37	764487.67E	260360.78N	8 June 93
KHV-38	771243.60E	238958.70N	9 June 93
KHV-39	769929.89E	247323.03N	9 June 93
KHV-40	767196.98E	264982.80N	8 June 93
KHV-41	768958.59E	263445.90N	8 June 93
KHV-42	773836.00E	233513.10N	9 June 93
KHV-44	762031.60E	200531.00N	13 June 93
KHV-45	764876.80E	171915.80N	17 June 93
KHV-46	764412.20E	223234.10N	10 June 93
KHV-47	765794.30E	188621.00N	13 June 93
KHV-48	769852.60E	171381.20N	17 June 93
KHV-49	770079.60E	204167.30N	10 June 93
KHV-50	771923.50E	198411.60N	11 June 93
KHV-51	772592.60E	181912.80.N	10 June 93

(Continued)

Table 1 (Concluded)

Core Name	Location		Date Collected
	Easting	Northing	
KHV-52	772754.50E	218753.70N	11 June 93
KHV-53	775645.90E	226680.80N	10 June 93
KHV-54	779070.80E	185140.90N	16 June 93
KHV-55	778548.00E	199533.80N	11 June 93
KHV-56	760909.40E	230660.50N	10 June 93
KHV-57	770713.80E	227991.20N	10 June 93
KHV-58	758236.63E	267199.32N	7 June 93
3-2	778020.21E	167548.83N	3 October 86
3-4	777598.08E	169156.47N	9 October 86
3-11	778501.91E	166490.25N	8 October 86
8-3	765376.46E	165178.20N	22 December 86
8-6	769838.08E	166600.81N	20 December 86

Table 2
Delaware Coast Geoacoustic Survey Core Analysis

Core ID	No.	Depth ft	Grain Size, mm/ϕ				Distribution, %				Percent Moisture w	Specific Gravity G_s	Sediment Type		
			D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Silt	Clay			Shepard(1954)	USCS	Wentworth
KHV-31	1	3.0	0.41 1.286	0.12 3.059	0.061 4.035	0.197 2.344		73	27				Silty Sand	SC	Fine Sand
KHV-32	1	0	0.68 0.556	0.48 1.059	0.39 1.358	0.517 0.952		100					Sand	SP	Coarse Sand
	2	3.0	0.38 1.396	0.13 2.943	0.072 3.796	0.194 2.366		80	20		11.0	2.08	Silty Sand	SC	Fine Sand
	3	4.0	0.40 1.322	0.12 3.059	0.049 4.351	0.190 2.396		81	19		10.60	2.66	Silty Sand	SC	Fine Sand
	4	7.0	0.50 1.0	0.28 1.837	0.205 2.286	0.328 1.608		100			7.44	2.78	Sand	SP	Medium Sand
KHV-33	1	2.0	0.47 1.089	0.32 1.644	0.28 1.837	0.357 1.486		100					Sand	SP	Medium Sand
	2	6.0	0.32 1.644	0.25 2.0	0.22 2.184	0.263 1.927		100					Sand	SP	Medium Sand
	3	11.0	0.42 1.252	0.28 1.837	0.22 2.184	0.307 1.927		100			4.60	2.60	Sand	SP	Medium Sand
	4	16.0	0.22 2.184	0.215 2.218	0.17 2.556	0.202 2.308		100			9.30	2.63	Sand	SP	Fine Sand
KHV-34	1	3.0	0.60 0.737	0.32 1.644	0.23 2.120	0.383 1.385		98	2		3.52	2.63	Sand	SP	Medium Sand
KHV-35	1	1.4	0.31 1.690	0.24 2.059	0.20 2.322	0.250 2.0		99	1		3.77	2.72	Sand	SP	Fine Sand
	2	8.0	0.36 1.474	0.27 1.889	0.22 2.184	0.283 1.821		100			3.58	2.80	Sand	SP	Medium Sand
	3	13.3	0.42 1.252	0.28 1.837	0.22 2.184	0.307 1.704		99	1		10.93	2.59	Sand	SP	Medium Sand
	4	16.0	0.36 1.474	0.27 1.889	0.21 2.252	0.280 1.837		100					Sand	SP	Medium Sand
KHV-36	1	1.5	1.1 -0.137	0.68 0.556	0.30 1.737	0.693 0.529		100			8.33	2.70			Coarse Sand

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ				Distribution, %				Percent Moisture w	Specific Gravity G_s	Sediment Type		
			D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Silt	Clay			Shepard(1954)	USCS	Wentworth
KHV-37	1	1.0	1.2 -0.263	0.77 .377	0.45 1.152	0.807 0.309		199			3.87	2.69	Sand	SP	Coarse Sand
	2	3.5	0.70 0.515	0.47 1.089	0.37 1.434	0.513 0.963		99	1		11.71	2.92	Sand	SP	Coarse Sand
	3	7.0	2.2 -1.137	0.72 0.474	0.42 1.252	1.113 -0.154	4	96			7.28	2.60	Sand	SP	Very Coarse Sand
	4	11.0	2.3 -1.202	0.81 0.304	0.43 1.218	1.180 -0.239	7	93			5.68	2.63	Sand	SP	Very Coarse Sand
	5	15.0	0.50 1.00	0.33 1.599	0.23 2.120	0.353 1.502		99	1		0.37	2.70	Sand	SP	Medium Sand
KHV-38	1	1.3	0.65 0.622	0.19 2.396	0.0019 9.040	0.281 1.831		58	9	33	16.67	1.89	Clayey Sand	SC	Medium Sand
	2	5.4	0.22 2.184	0.63 0.667	0.0023 8.764	0.284 1.816		63	13	24	19.08	1.86	Clayey Sand	SC	Medium Sand
	3	9.2	0.71 0.494	0.30 1.737	0.0032 8.288	0.338 1.565		78	4	18	14.47	1.98	Clayey Sand	SM	Medium Sand
	4	10.5	0.90 0.152	0.48 1.059	0.15 2.737	0.510 0.971	3	96	1		5.10	2.65	Sand	SP	Coarse Sand
	5	14.0	4.7 -2.233	1.8 -0.848	0.69 0.535	2.397 -1.261	21	77	1	1	3.54	2.70	Sand	SW	Granule Gravel
KHV-39	1	2.0	2.0 -1.0	0.72 0.474	0.32 1.644	1.013 -0.019	7	82	5	6			Sand	SC	Very Coarse, Sand
	2	6.6	0.31 1.690	0.12 3.059	0.022 5.506	0.151 2.727	1	78	9	12			Clayey Sand	SW	Fine Sand
	3	15.0	4.0 -2.0	1.1 -0.138	0.70 0.515	1.933 -0.951	14	86			5.95	2.57	Sand	GP	Very Coarse Sand
KHV-40	1	2.7	0.28 1.837	0.22 2.184	0.21 2.252	0.237 2.077		100			3.01	2.70	Sand	SP	Fine Sand
	2	7.5	0.25 2.0	0.21 2.252	0.19 2.396	0.217 2.204		100			0.81	2.68	Sand	SP	Fine Sand

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ				Distribution, %				Percent Moisture w	Specific Gravity G_s	Sediment Type		
			D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Silt	Clay			Shepard(1954)	USCS	Wentworth
KHV-40 (Cont)	3	12.6	0.25 2.0	0.21 2.252	0.17 2.556	0.210 2.252		99	1		0.93	2.73	Sand	SP	Fine Sand
	4	17.5	0.22 2.184	0.17 2.556	0.14 2.837	0.177 2.498		99	1		9.16	2.63	Sand	SP	Fine Sand
KHV-41	1	0.5	0.37 1.434	0.31 1.690	0.22 2.184	0.300 1.737		100			1.50	2.88	Sand	SP	Medium Sand
	2	3.2	0.40 1.322	0.35 1.515	0.33 1.599	0.360 1.474		100					Sand	SP	Medium Sand
	3	4.6	0.39 1.358	0.34 1.556	0.29 1.786	0.340 1.556		100			4.70	2.81	Sand	SP	Medium Sand
	4	7.1	0.39 1.358	0.29 1.786	0.24 2.059	0.307 1.704		100			3.95	2.72	Sand	SP	Medium Sand
	5	10.5	0.38 1.396	0.32 1.644	0.22 2.184	0.307 1.704	1	98	1		1.97	2.83	Sand	SP	Medium Sand
	6	17.0	0.38 1.396	0.31 1.690	0.22 2.184	0.303 1.723		100			3.21	2.85	Sand	SP	Medium Sand
KHV-42	1	0.5	8.4 -3.070	1.20 -0.263	0.43 1.218	3.343 -1.741	27	73			2.68	2.55	Sand	SW	Granule Gravel
	2	5.4	2.0 -1.0	0.79 0.340	0.49 1.029	1.093 -0.128	9	91			5.77	2.67	Sand	SW	Very Coarse Sand
	3	7.9	10.20 -3.351	0.78 0.358	0.4 1.322	3.793 -1.923	23	77			17.38	2.72	Sand	SW	Granule Gravel
	4	9.2	0.53 0.916	0.50 1.0	0.39 1.358	0.473 1.080	2	92	1		5.64	2.56	Sand	SP	Medium Sand
	5	12.8	1.20 -0.263	0.48 1.059	0.25 2.0	0.643 0.637	2	97	1		7.58	2.64	Sand	SW	Coarse Sand
	6	17.0	0.32 1.644	0.27 1.889	0.21 2.252	0.267 1.905		99	1		7.68	2.58	Sand	GP	Medium Sand
KHV-44	1	1.7	0.53 0.916	0.31 1.690	0.18 2.474	0.340 1.556		99	1		8.81	2.53	Sand	SP	Medium Sand

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ D_{84}	D_{50}	D_{16}	Mean	Distribution, % Gravel	Sand	Silt	Clay	Percent Moisture w	Specific Gravity G_s	Sediment Type Shepard(1954)	USCS	Wentworth
KHV-44 (Cont)	2	6.8	0.51 0.916	0.30 1.737	0.16 2.644	0.323 1.630		87	7	6	7.08	2.54	Sand	SP	Medium Sand
	3	8.0	0.70 0.515	0.46 1.120	0.31 1.690	0.490 1.029		100					Sand	SP	Medium Sand
	4	10.0	8.2 -3.036	3.9 -1.964	2.15 -1.104	4.75 -2.248		6346			7.43	2.67	Sand	SP	Pebble Gravel
	5	13.0	0.62 0.690	0.31 1.690	0.13 2.943	0.353 1.502	1	99			7.51	2.60	Sand	SP	Medium Sand
	6	17.0	0.83 0.269	0.38 1.396	0.21 2.252	0.473 1.080		99	1		7.21	2.69	Sand	SP	Medium Sand
	7	20.0	0.42 1.252	0.26 1.943	0.15 2.737	0.277 1.852		99	1		8.17	2.64	Sand	SP	Medium Sand
KHV-45	1	1.7	1.6 -0.678	0.73 0.454	0.39 1.358	0.907 0.141	5	94	1		11.85	2.63	Sand	SP	Coarse Sand
	2	6.0	2.2 -1.138	1.1 -0.138	0.58 0.786	1.293 -0.371	4	95	1		9.10	2.57	Sand	SP	Very Coarse Sand
	3	13.0	0.40 1.322	0.33 1.599	0.24 2.059	0.323 1.630	1	98	1		9.62	2.62	Sand	SP	Medium Sand
	4	14.7	0.71 0.494	0.42 1.252	0.37 1.434	0.50 1.0		100			11.11	2.57	Sand	SP	Coarse Sand
KHV-46	1	0.5	5.8 -2.536	0.40 1.322	0.15 2.737	2.117 -1.082	18	82			16.64	2.71	Sand	SP	Granule Gravel
	2	5.2	1.4 -0.485	0.63 0.667	0.42 1.252	0.817 0.292	2	98			13.76	2.63	Sand	SP	Coarse Sand
	3	15.2	2.7 -1.433	0.32 1.644	0.034 4.878	1.018 -0.026	8	69	15	8	18.75	2.59	Silty Sand	SM	Very Coarse Sand
	4	18.2	2.2 -1.138	0.78 0.358	0.34 1.556	1.107 -0.147	8	91	1		6.61	2.64	Sand	SW	Very Coarse Sand
KHV-47	1	7.0	1.6 -0.678	0.53 0.916	0.22 2.184	0.783 0.353	3	96	1		10.38	2.53	Sand	SW	Coarse Sand

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ D_{84}	D_{50}	D_{16}	Mean	Distribution, % Gravel	Sand	Silt	Clay	Percent Moisture w	Specific Gravity G_s	Sediment Type Shepard(1954)	USCS	Wentworth
KHV-47 (Cont)	2	11.0	1.4 -0.485	0.52 0.943	0.21 2.252	0.71 0.494		99	1		6.26	2.62	Sand	SP	Coarse Sand
	3	14.0	0.68 0.556	0.28 1.837	0.17 2.556	0.377 1.407		99	1		9.21	2.66	Sand	SP	Medium Sand
	4	17.5	0.77 0.377	0.28 1.837	0.18 2.474	0.410 1.286		99	1		5.95	2.86	Sand	SP	Medium Sand
KHV-48	1	2.0	10.7 -3.420	5.9 -2.561	0.14 2.837	5.58 -2.480	54	45	1		8.30	2.57	Sand	GW	Pebble Gravel
	2	8.0	1.2- 0.263	0.43 1.218	0.24 2.059	0.623 0.683		100			24.21	2.83	Sand	SW	Coarse Sand
	3	10.0	0.61 0.713	0.38 1.396	0.26 1.943	0.417 1.262	1	98	1		4.20	2.60	Sand	SW	Medium Sand
	4	15.0	2.8 -1.485	0.51 0.971	0.31 1.690	1.207 -0.271	5	95			11.02	2.58	Sand	SW	Very Coarse Sand
KHV-49	1	4.0	3.6 -1.848	1.1 -0.138	0.43 1.218	1.710 -0.774	7	93			3.47	2.76	Sand	SW	Very Coarse Sand
	2	9.0	0.40 1.322	0.22 2.184	0.13 2.943	0.250 2.0	1	99			6.41	2.	Sand	SP	Medium Sand
	3	11.0	8.1 -3.018	1.9 -0.926	0.40 1.322	3.467 -1.794	28	72			2.22	2.68	Sand	SW	Granule Gravel
	4	14.2	3.0 -1.585	0.43 1.218	0.31 1.690	1.247 -0.318	13	87			8.98	2.57	Sand	SW	Very Coarse Sand
	5	16.2	1.2 -0.263	0.52 0.943	0.41 1.286	0.710 0.494	6	94			9.54	2.47	Sand	SP	Coarse Sand
	6	17.7	6.3 -2.655	3.9 -1.964	1.2 -0.263	3.80 -1.926	33	67			0.34	2.71	Sand	SW	Granule Gravel
	7	19.0	8.0 -3.0	1.4 -0.482	0.43 1.218	3.277 -1.712	28	72			7.79	2.61	Sand	SW	Granule Gravel
KHV-50	1	2.5	5.0 -2.322	3.2 -1.678	2.3 -1.202	3.50 -1.807	16	84			7.06	2.62	Sand	SP	Granule Gravel

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ				Distribution, %				Percent Moisture w	Specific Gravity G_s	Sediment Type		
			D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Silt	Clay			Shepard(1954)	USCS	Wentworth
KHV-50 (Cont)	2	5.0	0.71 0.494	0.40 1.322	0.38 1.396	0.497 1.009		100			5.94	2.76	Sand	SP	Coarse Sand
	3	10.0	0.70 0.515	0.52 0.943	0.51 0.971	0.577 0.793	1	99			3.56	2.81	Sand	SP	Coarse Sand
	4	14.0	0.78 0.358	0.46 1.120	0.35 1.515	0.530 0.916		100			3.62	2.81	Sand	SP	Coarse Sand
	5	18.0	0.70 0.515	0.41 1.286	0.31 1.690	0.473 1.080		100			5.97	2.81	Sand	SP	Medium Sand
KHV-51	1	1.0	6.0 -2.585	1.0 0.0	0.42 1.252	2.473 -1.306	22	78			7.79	2.56	Sand	GW	Granule Gravel
	2	2.0	0.26 1.943	0.80 0.322	0.39 1.358	0.483 1.050	10	89	1		4.06	2.60	Sand	SW	Medium Sand
	3	2.7	10.3 -3.365	1.8 -0.848	0.37 1.434	4.157 -2.056	37	62	1				Sand	SW	Pebble Gravel
	4	3.6	0.72 0.474	0.51 0.971	0.30 1.737	0.510 0.971		100			5.48	2.57	Sand	SP	Coarse Sand
	5	5.0	3.8 -1.926	0.31 1.690	0.0034 8.20	1.371 -0.455	9	64	10	17	11.31	2.49	Clayey Sand	SC	Very Coarse Sand
	6	6.0	0.71 0.494	0.52 0.943	0.42 1.252	0.550 0.863		100			9.31	2.55	Sand	SP	Coarse Sand
	7	11.5	1.2 -0.263	0.52 0.943	0.28 1.837	0.667 0.584	2	98			2.10	2.57	Sand	SW	Coarse Sand
	8	13.0	0.70 0.515	0.57 0.811	0.34 1.556	0.537 0.897	1	99			0.69	2.74	Sand	SP	Coarse Sand
	9	16.0	4.2 -2.070	0.87 0.201	0.53 0.916	1.867 -0.901	13	86	1		5.78	2.70	Sand	SW	Very Coarse Sand
KHV-52	1	1.5	7.0 -2.807	1.1 -0.138	0.40 1.322	2.833 -1.502	24	76			7.62	2.62	Sand	SW	Granule Gravel
	2	5.3	0.88 0.184	0.35 1.515	0.22 2.184	0.483 1.050		100					Sand	SP	Medium Sand

Table 2 (Continued)

Core ID	No.	Depth ft	Grain Size, mm/ϕ D_{84}	D_{50}	D_{16}	Mean	Distribution, % Gravel	Sand	Silt	Clay	Percent Moisture w	Specific Gravity G_s	Sediment Type Shepard(1954)	USCS	Wentworth
KHV-52 (Cont)	3	6.6	1.2 -0.263	0.41 1.286	0.091 3.458	0.567 0.819	7	92	1				Sand	SP	Coarse Sand
	4	8.5	8.8 -3.138	4.2 -2.070	1.1 -0.138	4.70 -2.233	42	58			0.72	2.72	Sand	SW	Pebble Gravel
	5	10.6	1.2 -0.263	0.88 0.184	0.52 0.943	0.867 0.206		100			8.15	2.55	Sand	SP	Coarse Sand
	6	14.4	1.2 -0.263	0.81 0.304	0.57 0.811	0.860 0.218	1	99			9.27	2.53	Sand	SP	Coarse Sand
	7	18.2	1.2 -0.263	0.81 0.304	0.58 0.786	0.863 0.213		100			9.82	2.63	Sand	SP	Coarse Sand
KHV-53	1	10.0	0.30 1.737	0.13 2.943	0.004 7.966	0.535 0.902		70	14	16	14.54	2.24	Silty Sand	SC	Coarse Sand
KHV-54	1	0.4	6.8 -2.766	3.5 -1.807	0.92 0.120	3.740 -1.903	35	65			11.99	2.75	Sand	SW	Granule Gravel
	2	1.4	1.6 -0.678	0.62 0.690	0.43 1.218	0.883 0.180	4	96			9.12	2.64	Sand	SP	Coarse Sand
	3	4.3	0.28 1.837	0.14 2.837	0.0034 8.20	0.1411 2.825		82	7	11	12.97	2.17	Sand	SC	Fine Sand
KHV-55	1	1.8	0.42 1.252	0.21 2.252	0.12 3.059	0.250 2.0		100			10.59	2.60	Sand	SP	Fine Sand
	2	4.0	2.2 -1.138	0.75 0.415	0.43 1.218	1.127 -0.172		93	7		9.43	2.64	Sand	SP	Very Coarse Sand
	3	4.5	1.6 -0.678	0.78 0.358	0.42 1.252	0.933 0.10	2	98					Sand	SP	Coarse Sand
	4	9.8	1.0 0.0	0.52 0.943	0.25 2.0	0.590 0.761	1	99			11.56	2.64	Sand	SP	Coarse Sand
KHV-56	1	0.5	2.8 -1.485	1.1 -0.138	0.58 0.786	1.493 -0.578	5	95			11.61	2.75	Sand	SW	Very Coarse Sand
	2	3.0	1.7 -0.766	0.84 0.252	0.42 1.252	0.987 0.019	4	96			9.34	2.64	Sand	SP	Coarse Sand

Table 2 (Concluded)

Core ID	No.	Depth ft	Grain Size, mm/ϕ				Distribution, %				Percent Moisture w	Specific Gravity G_s	Sediment Type		
			D_{84}	D_{50}	D_{16}	Mean	Gravel	Sand	Silt	Clay			Shepard(1954)	USCS	Wentworth
KHV-56 (Cont)	3	5.0	2.5 -1.322	1.1 -0.138	0.54 0.889	1.380 -0.465	8	92					Sand	SP	Very Coarse Sand
	4	15	0.52 0.943	0.12 3.059	0.039 4.680	0.226 2.146	2	66	21	11	17.86	2.87	Silty Sand	SC	Fine Sand
KHV-57	1	1.7	1.0 0.0	0.53 0.916	0.072 3.796	0.534 0.905	7	79	9	5			Sand	SC	Coarse Sand
KHV-58	1	0.5	5.3 -2.406	0.70 0.515	0.28 1.837	2.093 -1.066	8	91	1		5.11	2.75	Sand	SW	Granule Gravel
	2	3.0	0.36 1.474	0.29 1.786	0.22 2.184	0.290 1.786		100			9.73	2.54	Sand	SP	Medium Sand
	3	8.3	0.34 1.556	0.20 2.322	0.031 5.012	0.190 2.396		72	19	9	5.90	2.61	Silty Sand	SC	Fine Sand
	4	9.6	0.87 0.201	0.43 1.218	0.24 2.059	0.513 0.963		98	2				Sand	SP	Coarse Sand
	5	13.0	0.78 0.358	0.44 1.184	0.27 1.889	0.497 1.009		100			7.92	2.65	Sand	SP	Coarse Sand
	6	19.5	0.72 0.474	0.35 1.515	0.26 1.943	0.443 1.175		100			12.64	2.57	Sand	SP	Medium Sand

(Sheet 8 of 8)

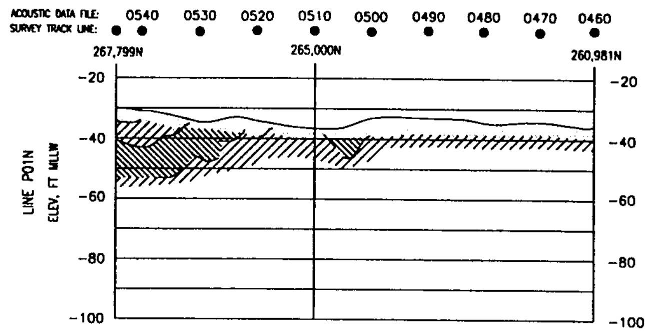
Table 3
New Jersey Coast Sediment Description

Density, g/cm^3	Mean Grain Size ϕ_m	Basic Sediment Description
1.0 - 1.4	Outside model boundary	Soft muds, clays
1.4 - 1.6	> 4	Clays, silts, sandy silts
1.6 - 1.8	4 - 2.2	Clayey sands, silty sands
1.8 - 2.0	2.2 - 1.2	Fine sands
2.0 - 2.2	1.2 - 0	Medium sands
> 2.2	< 0	Coarse sands and gravels, clayey sands with gravels

Table 4
Acoustic Versus Sediment Properties

Core Data (KHV only)					Acoustic Measurements				
ID	No.	Type[1]	ϕ_{mm}	ρ,g/cm^3	Z x 10^2g/cm^{2}sec	*R*	*BL*, db[2]	ϕ_{mc}	ρ g/cm^3
31	1	SC	2.34	1.80	2746	0.29	10.96	1.80	1.70
32	1	SP	0.95	2.10	3370	0.37	8.97	0.90	1.95
33	1	SP	1.49	2.04	3399	0.38	8.58	0.90	1.98
35	1	SP	2.00	2.00	2607	0.27	11.92	1.87	1.62
36	1	SP	0.53	2.14	3589	0.40	8.05	0.40	2.02
37	1	SP	0.31	2.20	3194	0.34	9.95	1.25	1.85
38	1	SC	1.83	2.00	3997	0.45	7.10	1.20	2.15
39	1	SC	-0.02	2.27	4017	0.45	7.18	-0.70	2.10
40	1	SP	2.08	1.99	3032	0.37	9.56	1.51	1.88
41	1	SP	1.74	2.03	2845	0.31	10.30	2.00	1.87
42	1	SW	-1.74	-	3647	0.41	7.88	0.20	2.13
44	1	SP	1.56	2.04	3260	0.37	8.78	1.13	2.03
45	1	SP	0.14	2.24	2903	0.32	10.30	2.00	1.86
46	1	SP	-1.08	N/A	4105	0.46	6.79	-0.62	2.27
48	1	GW	-2.48	-	4440	0.49	6.39	-1.21	2.35
49	1	SW	-0.77	-	3605	0.39	8.62	0.53	2.08

[1] Unified Soil Classification. Refer also to Table 2.
[2] $BL = 20 \log_{10}(R)$



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coorse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

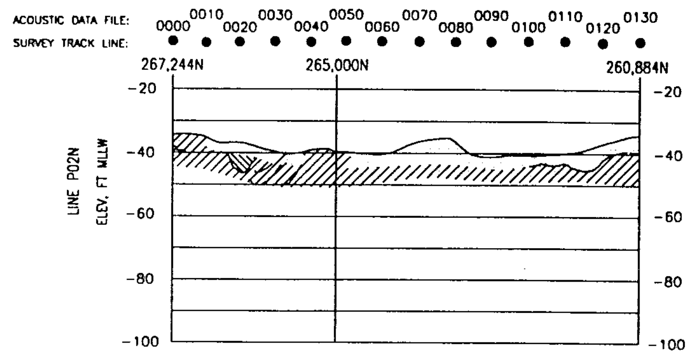
SCALE
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P01N-N

FILE NAME: P01N-N.DWG
SCALE: 1" = 1000' | DATE: AUGUST 8, 1995 | PLATE 1

Plate 2



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

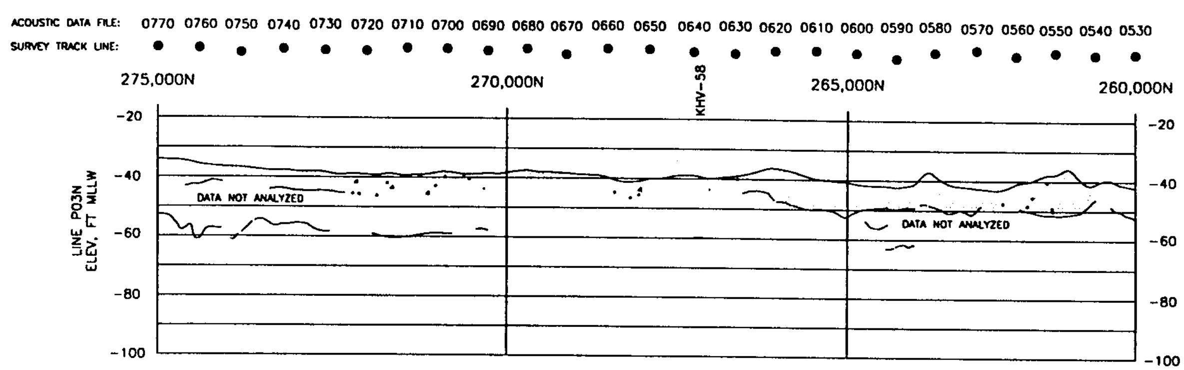
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P02N-N

FILE NAME: P02N-N.DWG

SCALE: 1" = 1000' | DATE: AUGUST 8, 1995 | PLATE 2



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

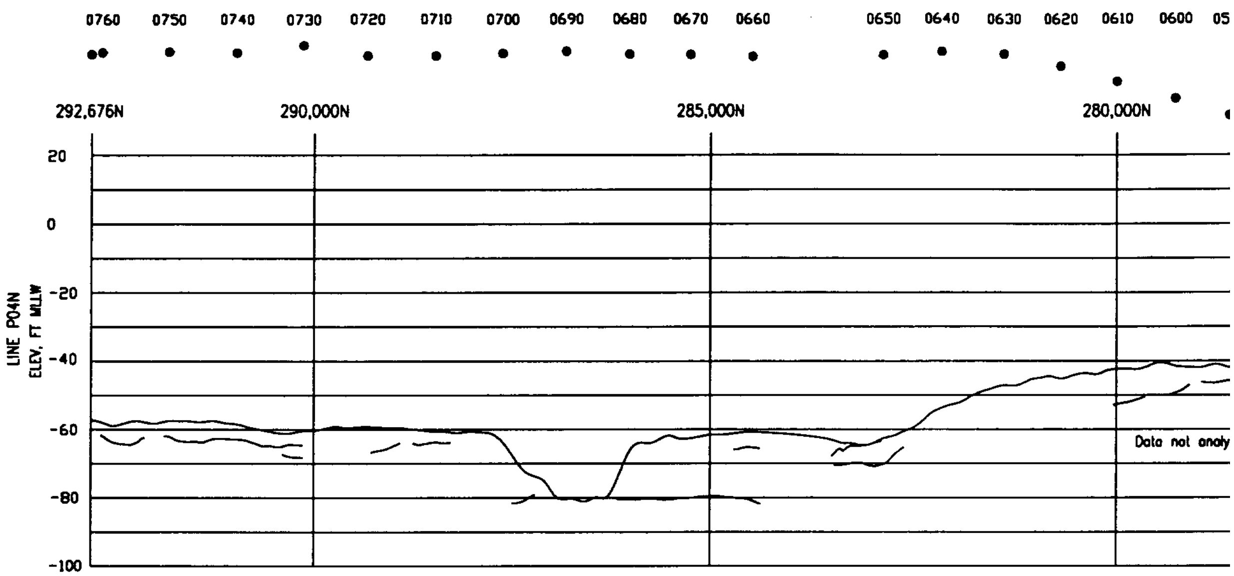
- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

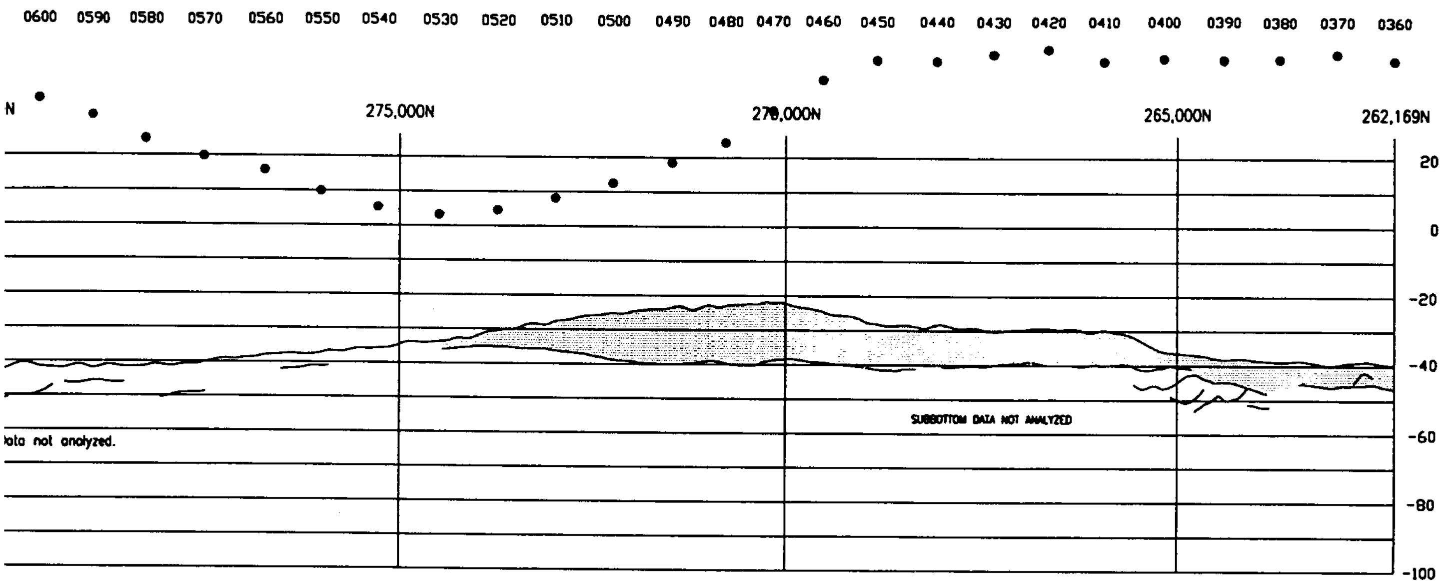
DELAWARE COAST
LINE P03N-N

FILE NAME: P03N-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 3



DELAWARE CO	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEM



WARE COAST SEDIMENT DESCRIPTION

Density gm/cc	Mean Grain Size, ϕ m	Basic Soil Description
1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
1.8 - 2.0	2.2 - 1.2	Fine Sands
2.0 - 2.2	1.2 - 0	Medium Sands
> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

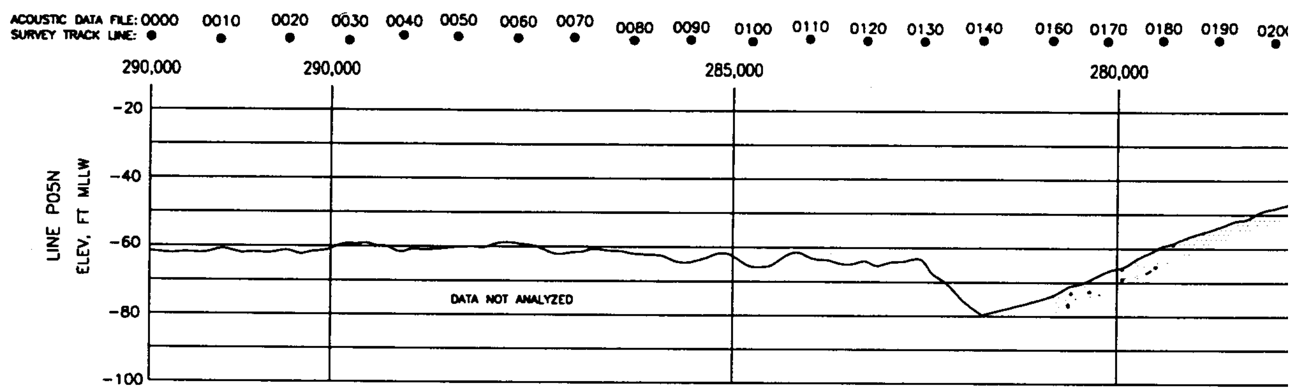
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P04N-N

FILE NAME: P04N-N.DWG

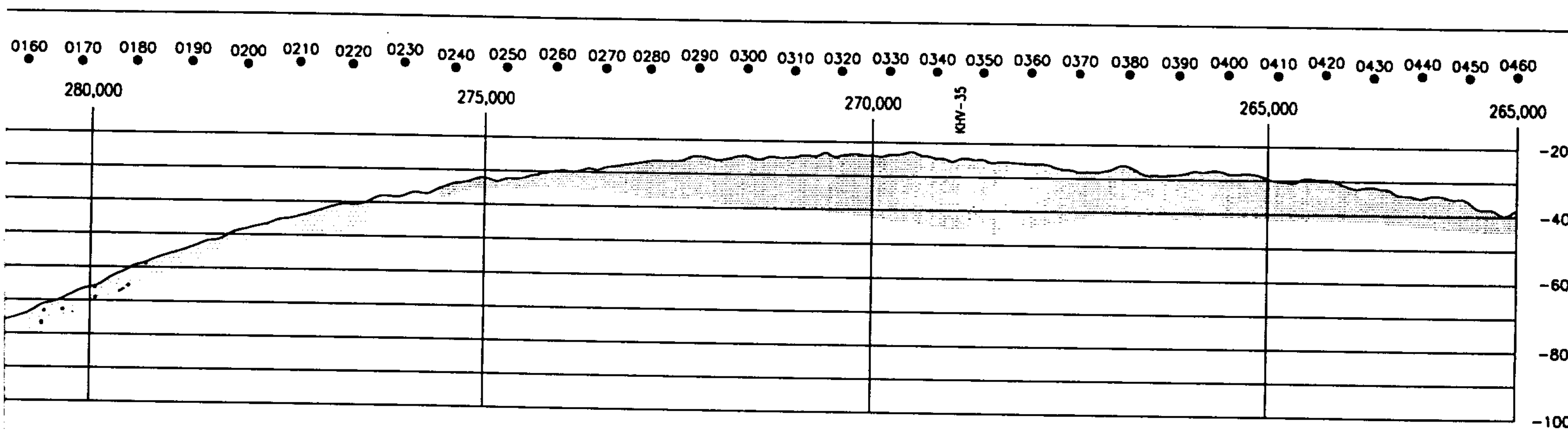
SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 4



DELAWARE CO	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMENT (

0



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
Dashed lines	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
Dense diagonal hatching	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
Diagonal hatching	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
Fine stipple	1.8 - 2.0	2.2 - 1.2	Fine Sands
Blank	2.0 - 2.2	1.2 - 0	Medium Sands
Scattered dots	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

0 1000 2000 FT

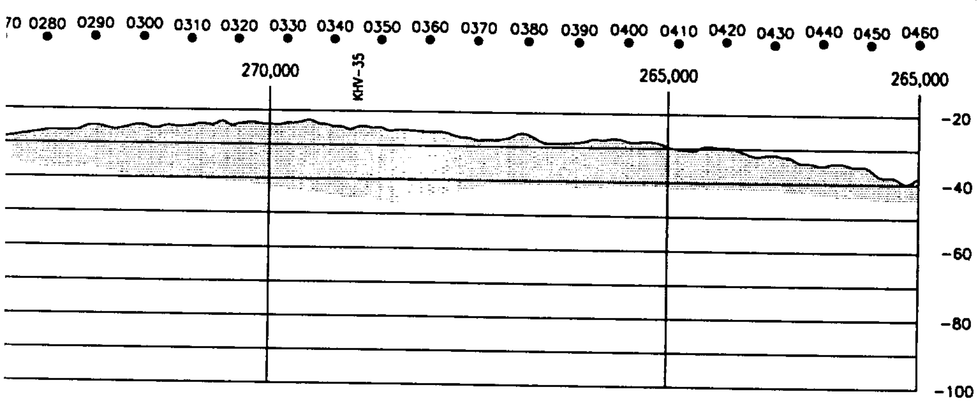
WATERWAYS EXPERIMENT STA
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P05N-N

FILE NAME: P05N-N.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE

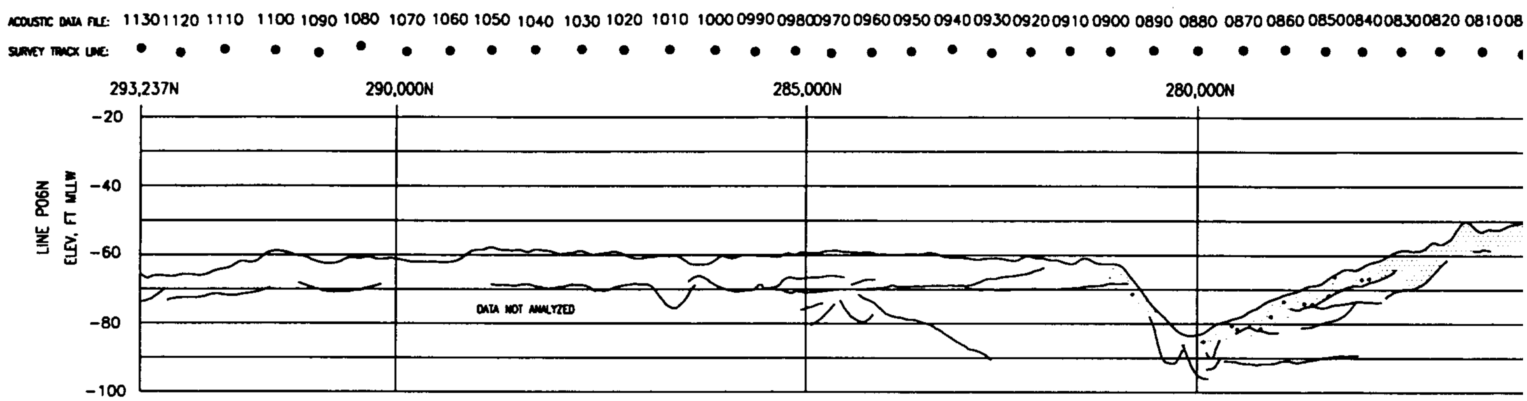
F



WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P05N-N

FILE NAME: P05N-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 5



DELAWARE COAST SEDIMENT DES			
Hatch Pattern	Density gm/cc	Mean Grain Size, ɸ m	
	1.0 - 1.4	Outside Model Boundary	Soft M
	1.4 - 1.6	> 4	Clays, Sandy
	1.6 - 1.8	4 - 2.2	Clayey Silty S
	1.8 - 2.0	2.2 - 1.2	Fine S
	2.0 - 2.2	1.2 - 0	Medium
	> 2.2	< 0	Coarse Clayey

NOTES

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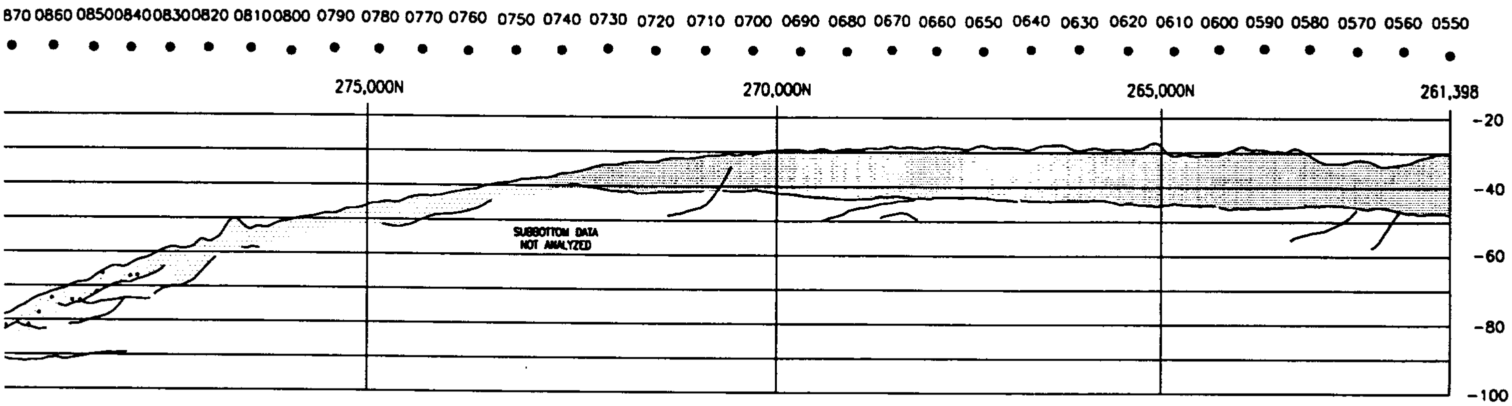
SCALE

0 1000 2000 FT



VARE COAST SEDIMENT DESCRIPTION		
Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
1.8 - 2.0	2.2 - 1.2	Fine Sands
2.0 - 2.2	1.2 - 0	Medium Sands
> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

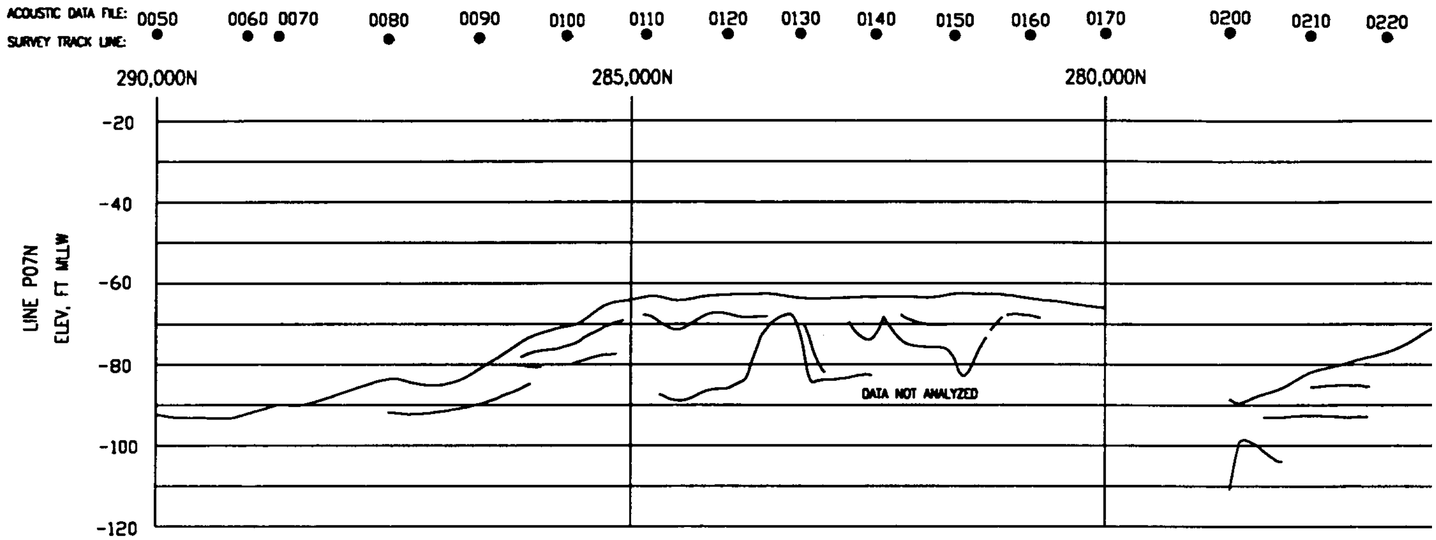
SCALE
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P06N-N

FILE NO. P06N-N

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 6



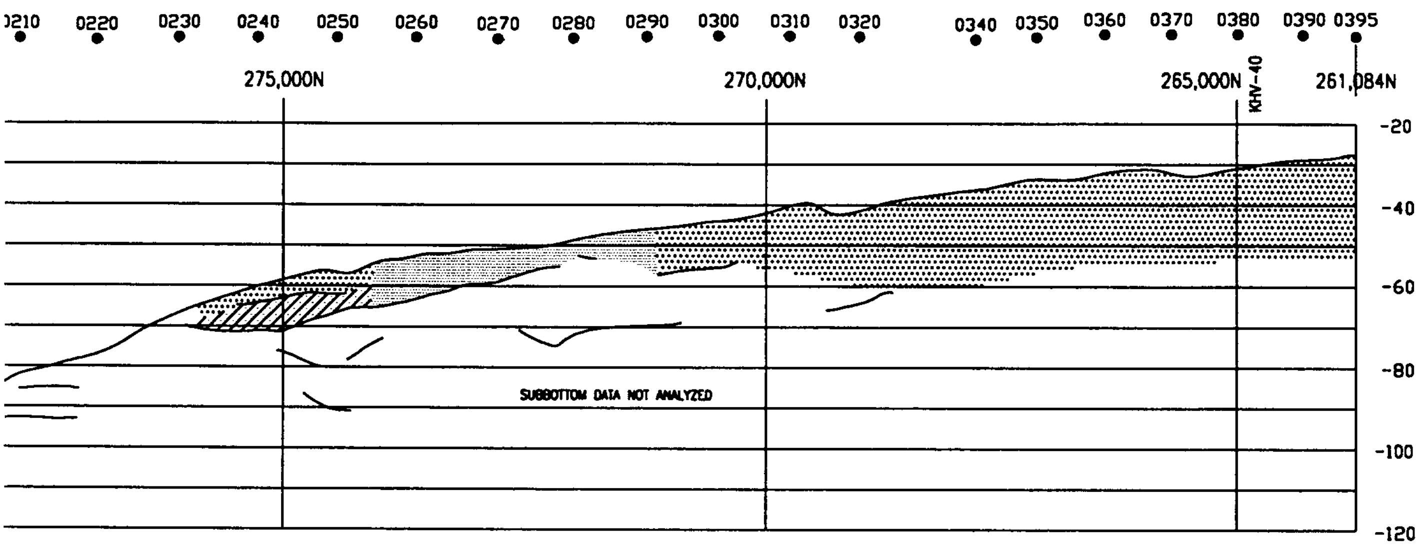
DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	<

NOTES

- DATA BASEMENT DEFINED BY

SCALE

0 1000



COAST SEDIMENT DESCRIPTION

ty :c	Mean Grain Size, ϕ m	Basic Soil Description
1.4	Outside Model Boundary	Soft Muds, Clays
1.6	> 4	Clays, Silts, Sandy Silts
1.8	4 - 2.2	Clayey Sands, Silty Silts
2.0	2.2 - 1.2	Fine Sands
2.2	1.2 - 0	Medium Sands
2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

MENT DEFINED BY BOTTOM OF HATCHING

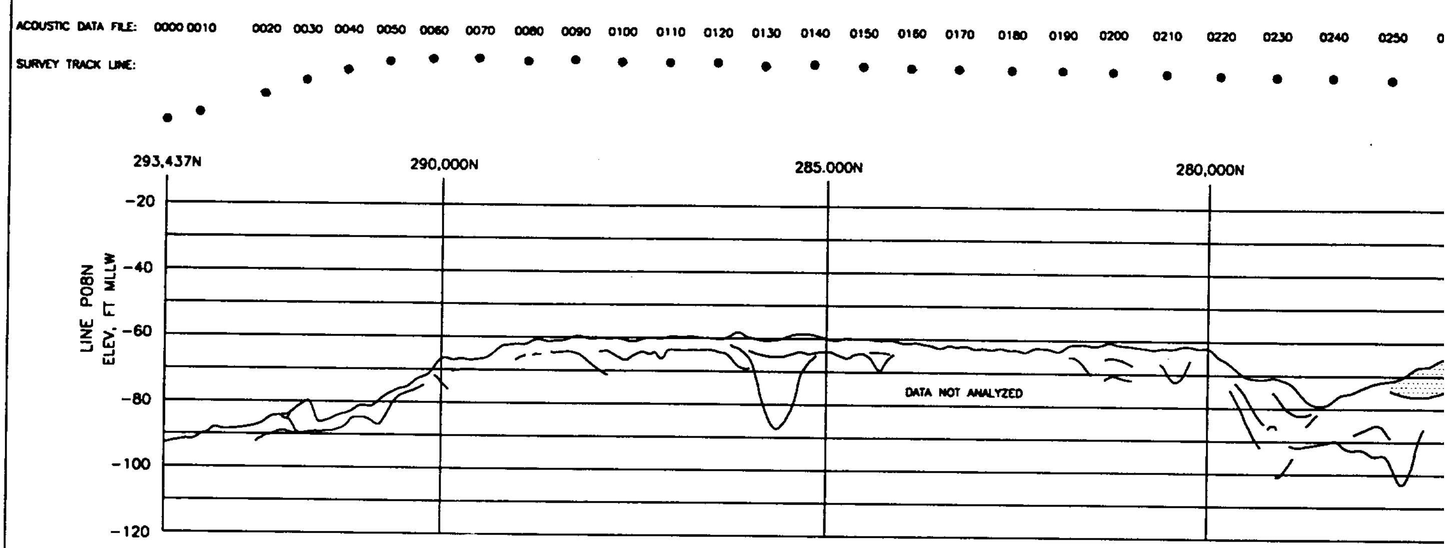
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P07N-N

FILE NAME: P07N-N.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 8, 1995	PLATE 7

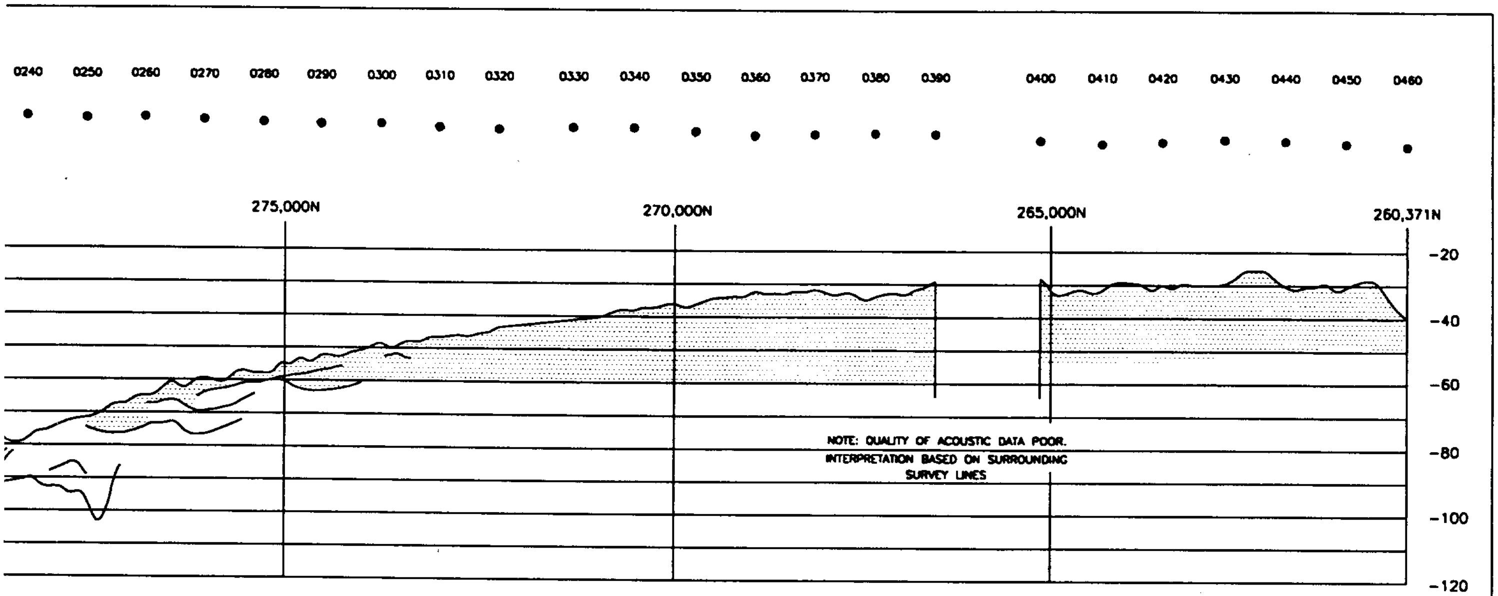


DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	<

NOTE

- DATA BASEMENT DEFINED BY E

SCAL
0 1000



RE COAST SEDIMENT DESCRIPTION

)ensity]m/cc	Mean Grain Size, Φ m	Basic Soil Description
0 - 1.4	Outside Model Boundary	Soft Muds, Clays
4 - 1.6	> 4	Clays, Silts, Sandy Silts
6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
8 - 2.0	2.2 - 1.2	Fine Sands
.0 - 2.2	1.2 - 0	Medium Sands
> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

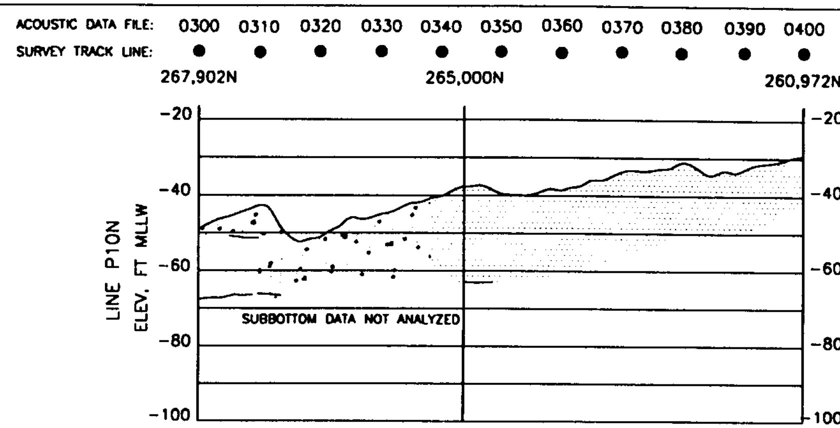
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P08N-N

FILE NAME: P08N-N.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 8



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

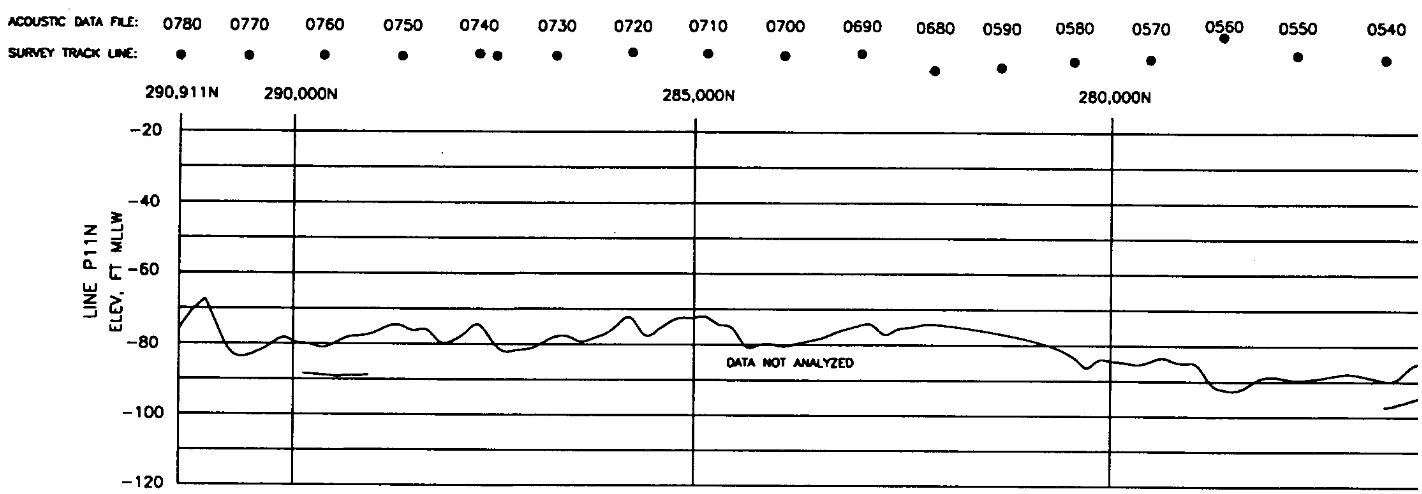
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P10N-N

FILE NAME: P10N-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 9



DELAWARE COAST S		
Hatch Pattern	Density gm/cc	Me Si
	1.0 - 1.4	Outs B
	1.4 - 1.6	
	1.6 - 1.8	4
	1.8 - 2.0	2.2
	2.0 - 2.2	1.
	> 2.2	

NO

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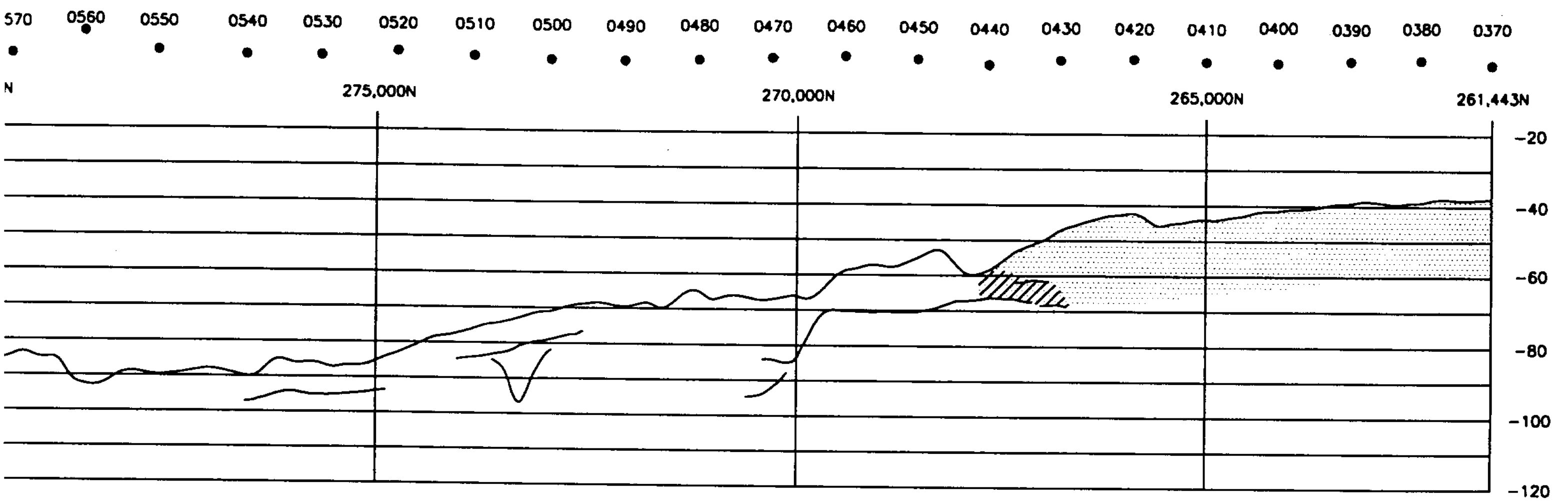


DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

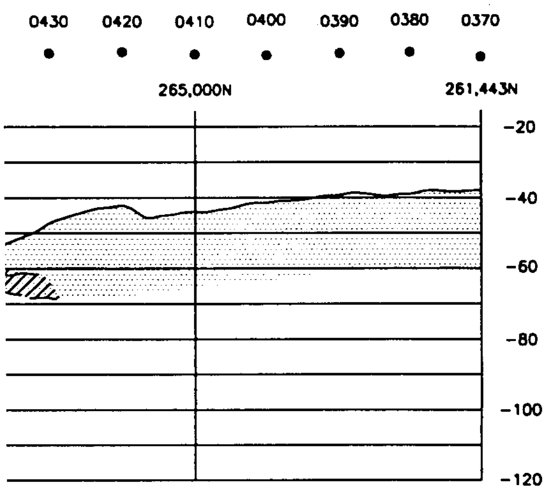
SCALE
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

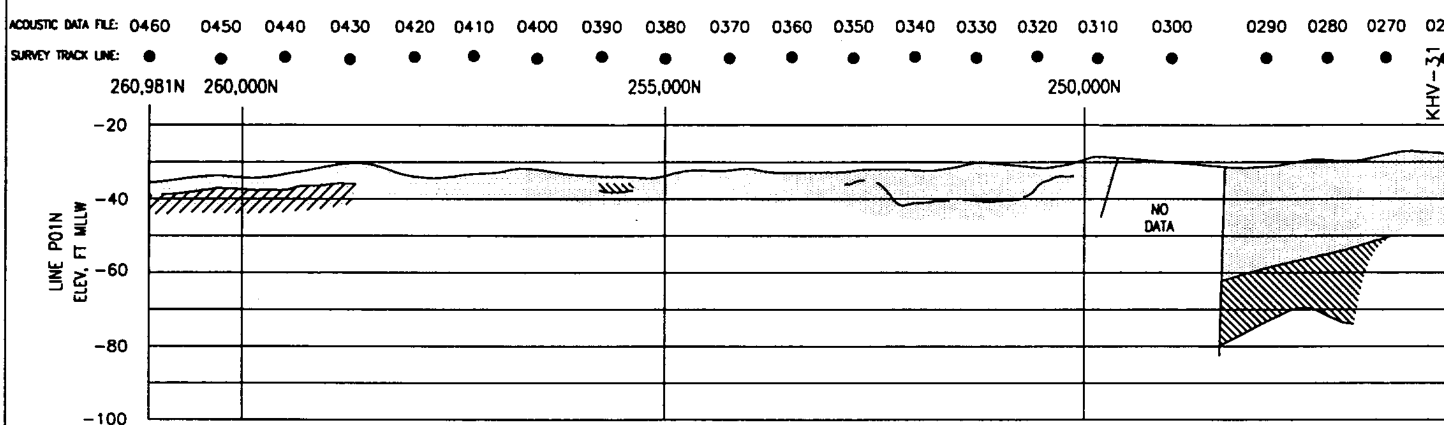
DELAWARE COAST
LINE P11N-N

FILE NO. P11N-N.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 10



WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE COAST LINE P11N-N		
FILE NO. P11N-N.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 8, 1995	PLATE 10



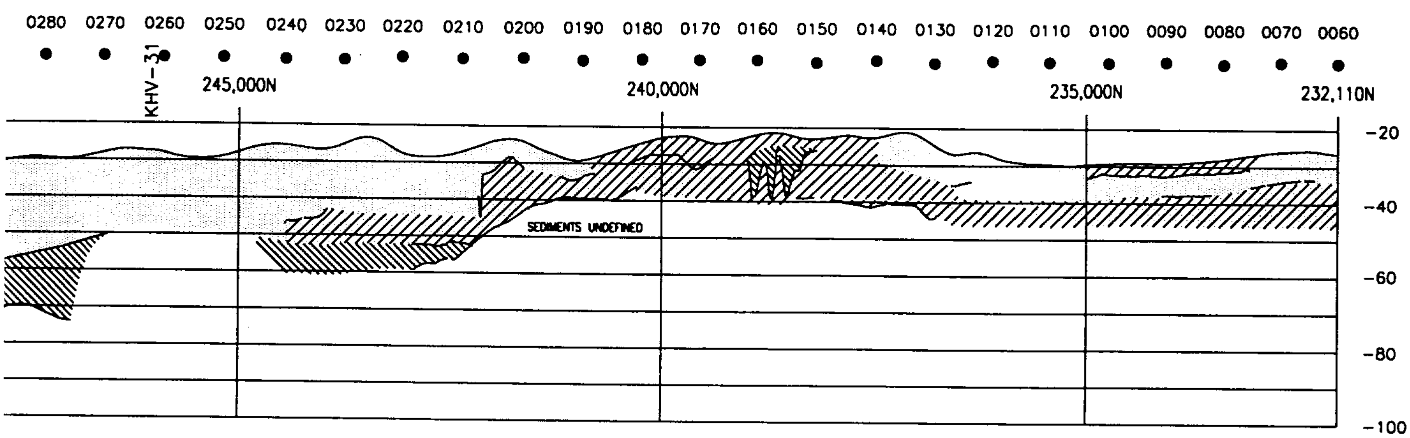
DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Bou
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2
	2.0 - 2.2	1.2
	> 2.2	<

NOT

• DATA BASEMENT DEFINED

SCA

0 10



RE COAST SEDIMENT DESCRIPTION

Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
.4 - 1.6	> 4	Clays, Silts, Sandy Silts
.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
.8 - 2.0	2.2 - 1.2	Fine Sands
.0 - 2.2	1.2 - 0	Medium Sands
> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

TA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

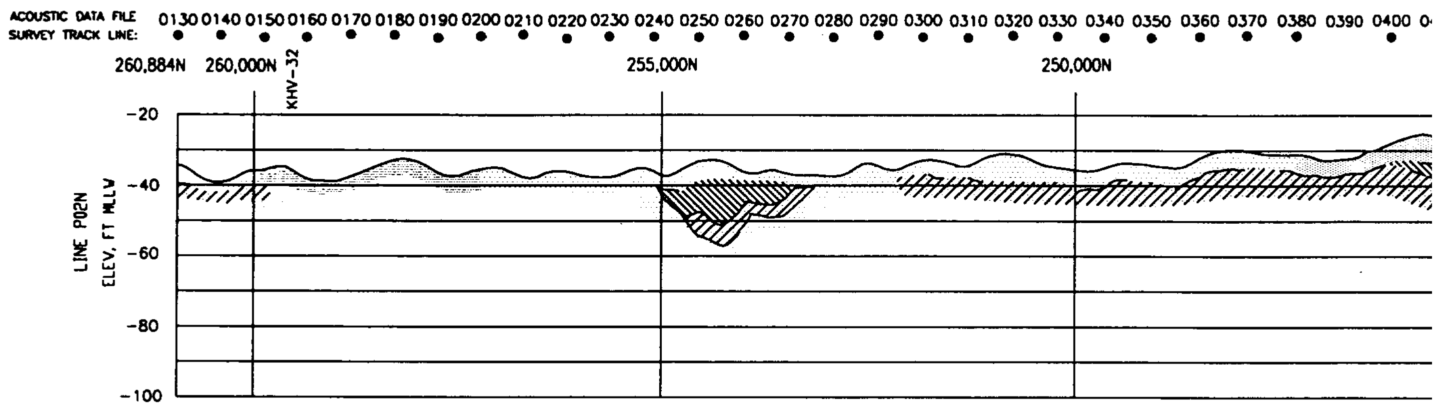
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P01N-S

FILE NAME: P01N-S.DWG

SCALE: 1" = 1000' | DATE: AUGUST 8, 1995 | PLATE 11



DELAWARE COAST SEDIMENT			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	
	1.0 - 1.4	Outside Model Boundary	S
	1.4 - 1.6	> 4	C S
	1.6 - 1.8	4 - 2.2	C S
	1.8 - 2.0	2.2 - 1.2	F
	2.0 - 2.2	1.2 - 0	M
	> 2.2	< 0	C C

NOTES

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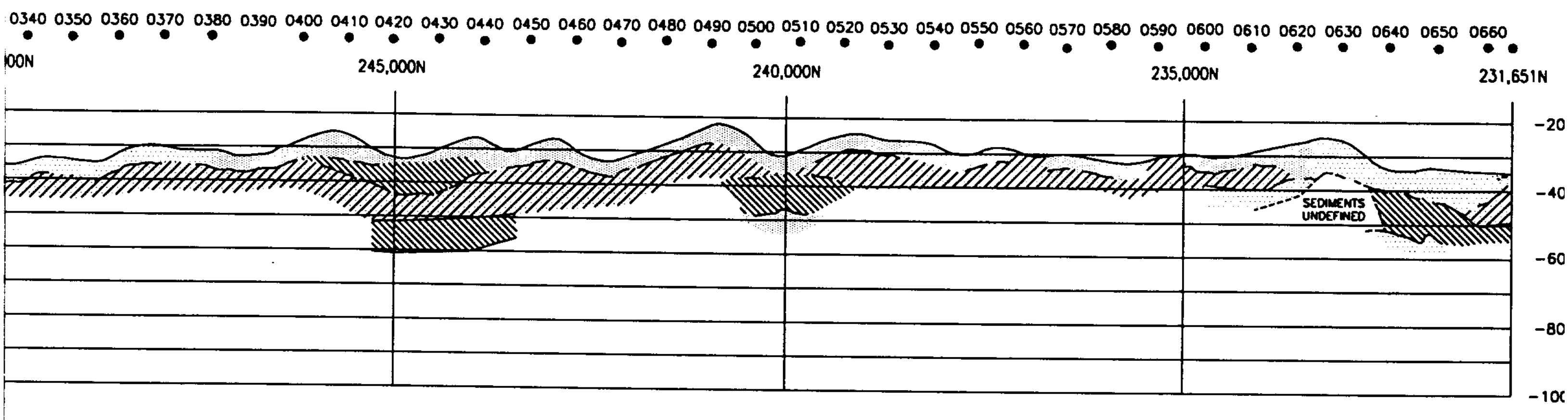
SCALE

0 1000 2000



DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT ST
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P02N-S

FILE NAME P02N-S.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLAT

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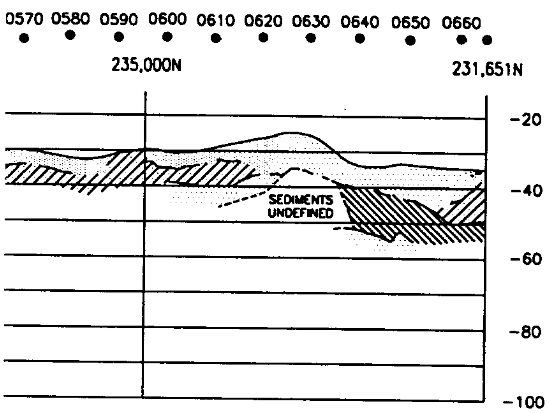
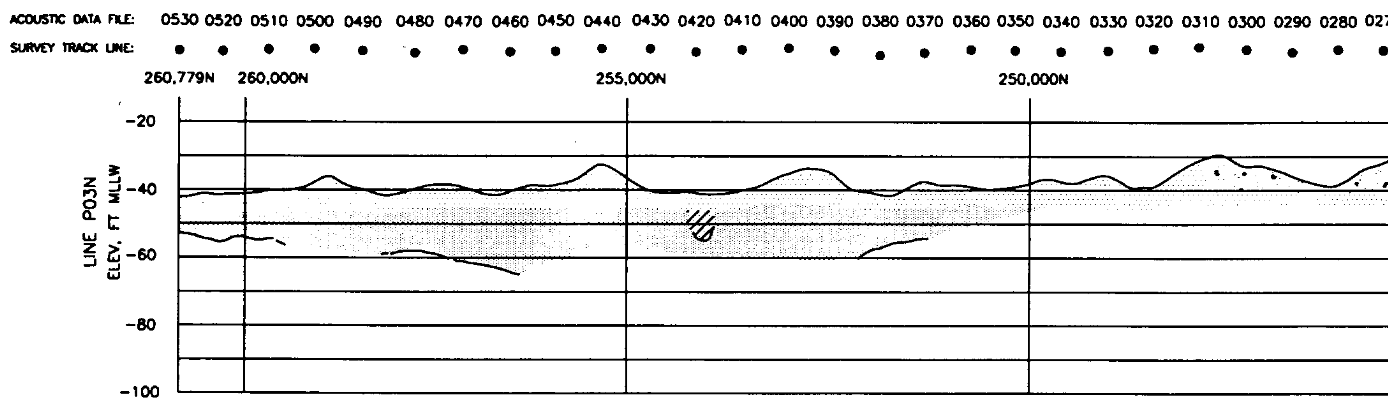


WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE COAST LINE P02N-S		
FILE NAME P02N-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 12



DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Bound
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	<

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• DATA BASEMENT DEFINED

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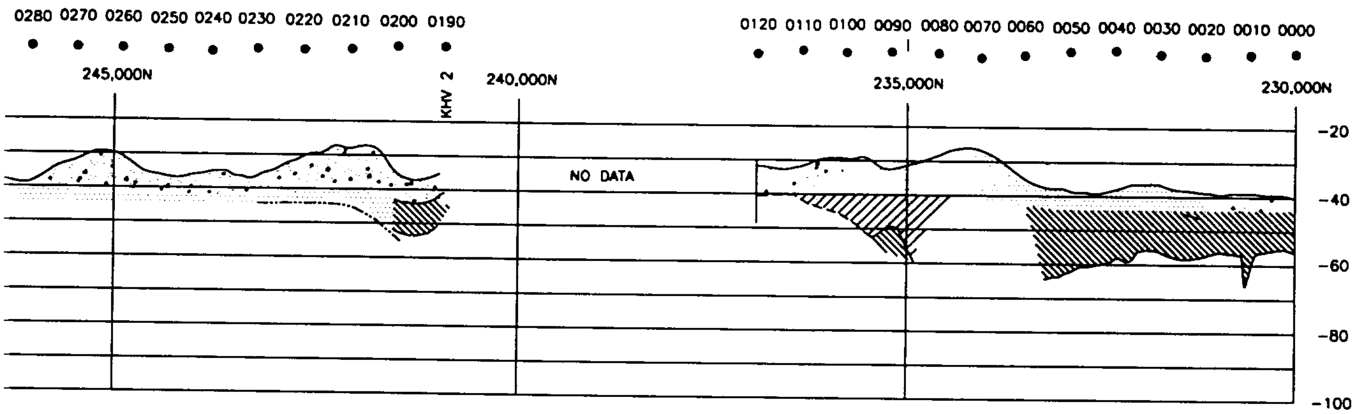

ST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

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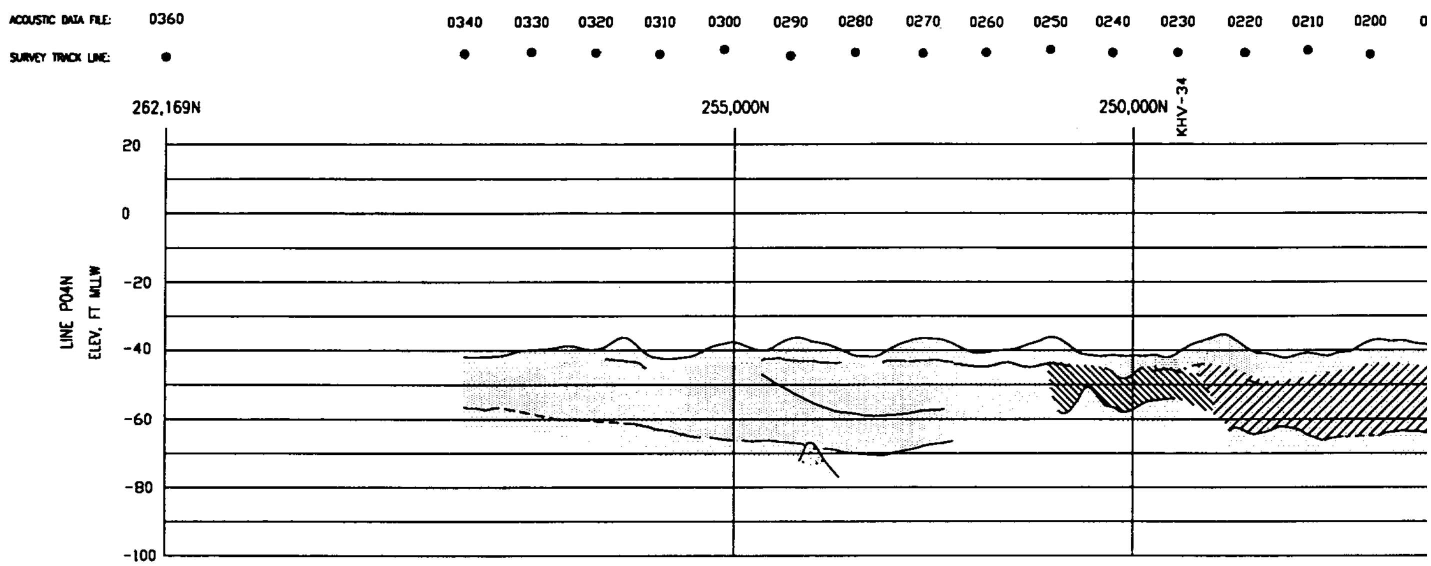
SCALE

1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P03N-S

FILE NAME: P03N-S.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 8, 1995	PLATE 13



DELAWARE COAST SEDIMEN		
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m
	1.0 - 1.4	Outside Model Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	< 0

NOTES

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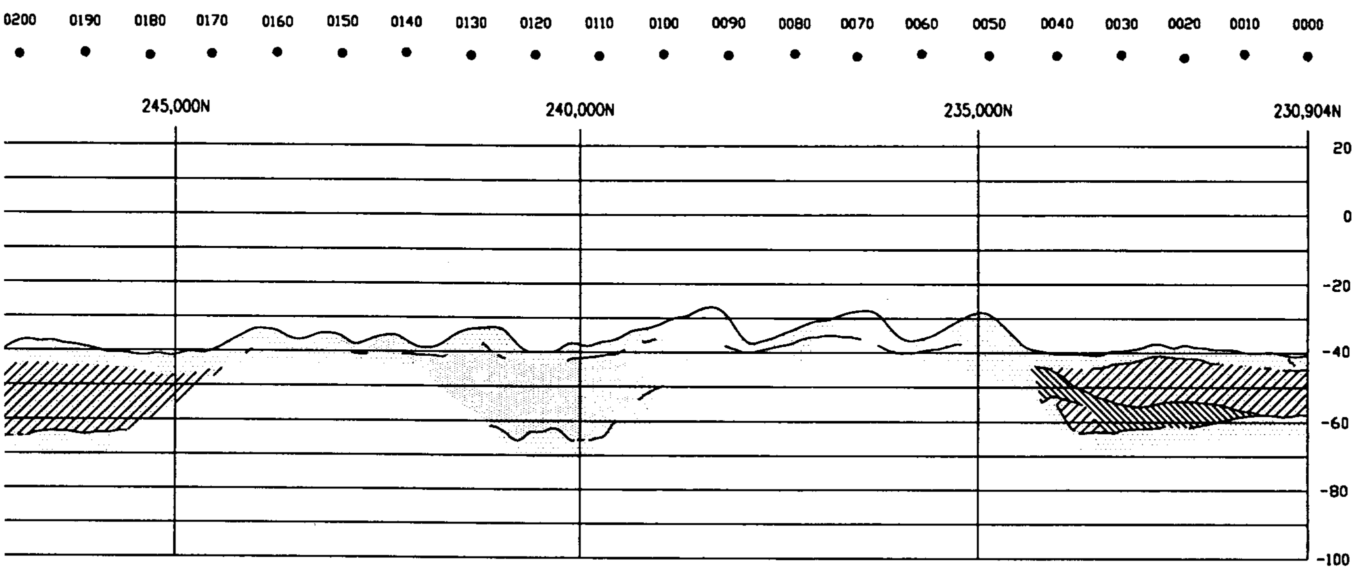

EDIMENT DESCRIPTION	
on Grain e, Φm	Basic Soil Description
ide Model oundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
- 2.2	Clayey Sands, Silty Silts
2 - 1.2	Fine Sands
.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

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) BY BOTTOM OF HATCHING

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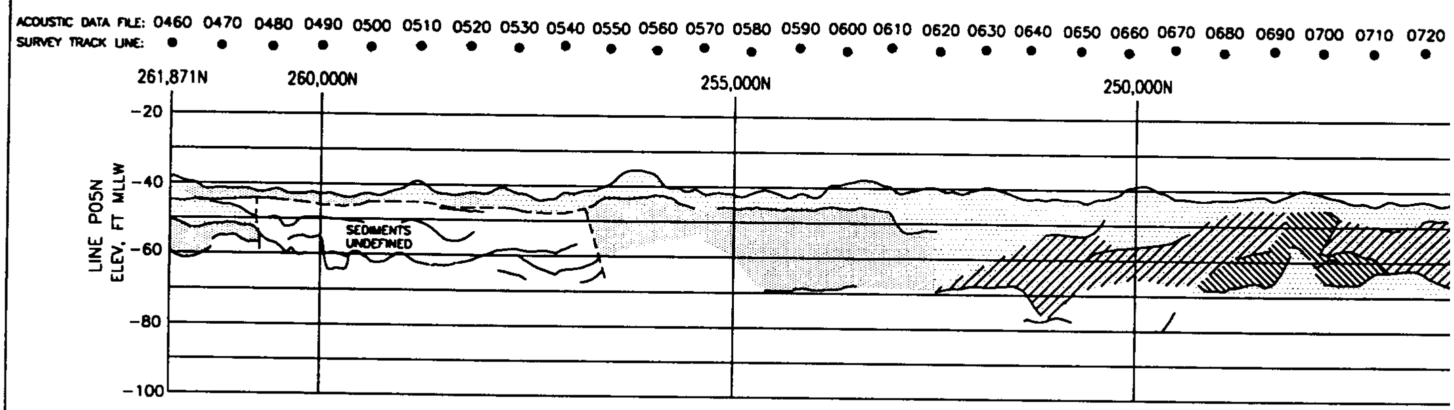
0 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P04N-S

FILE NAME: P04N-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 14



DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Bound
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	< (

NOTE

- DATA BASEMENT DEFINED BY

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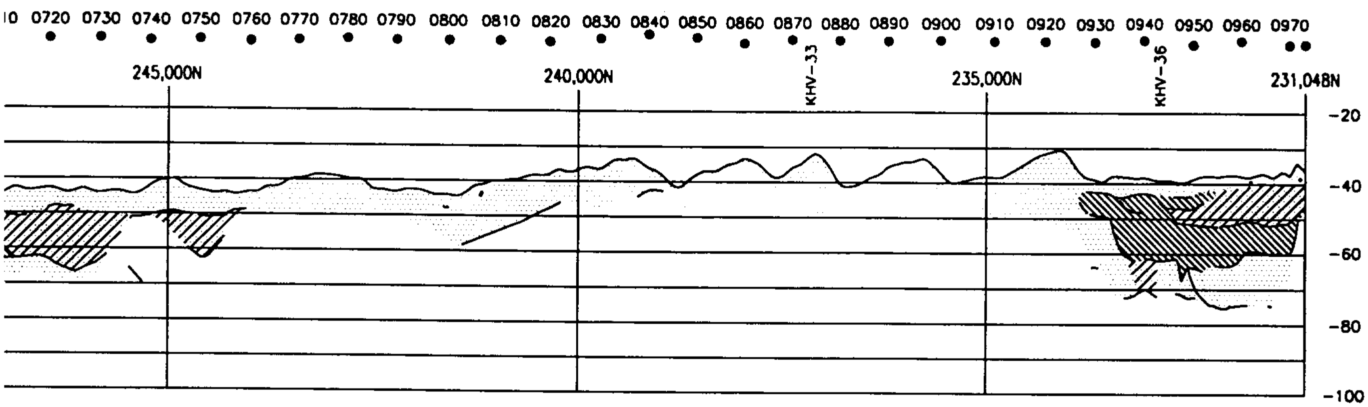
0 1000



ST SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

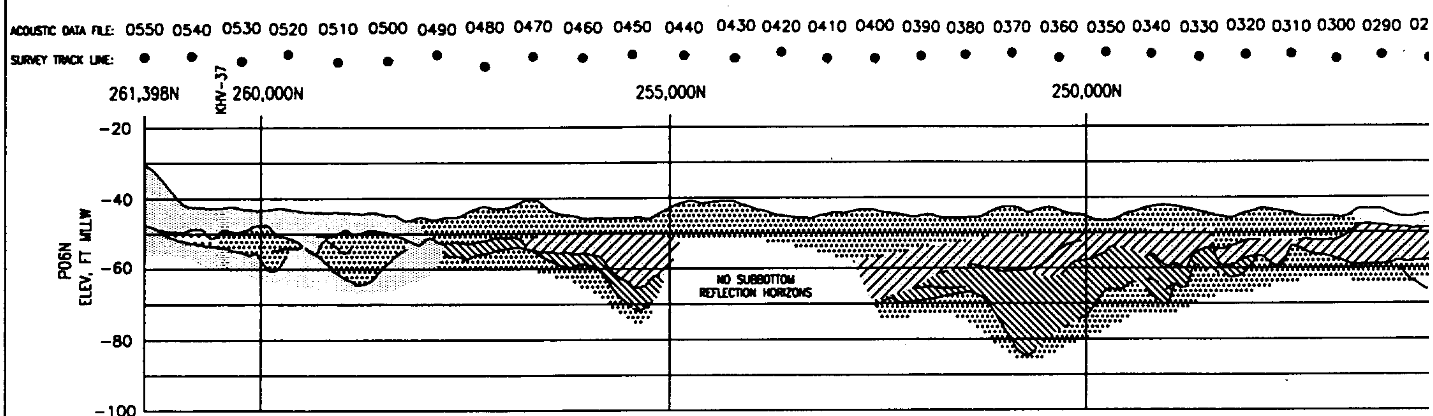
NOTES

DEFINED BY BOTTOM OF HATCHING

SCALE

1000 2000 FT

WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE COAST LINE P05N-S		
FILE NAME: P05N-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 15



DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	<

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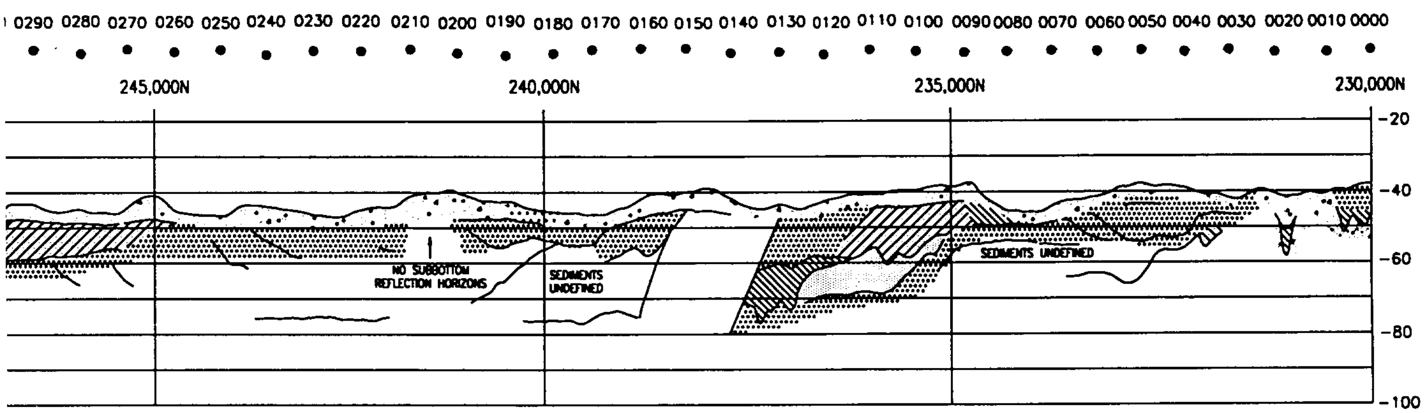
0 100



ST SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

DEFINED BY BOTTOM OF HATCHING

SCALE

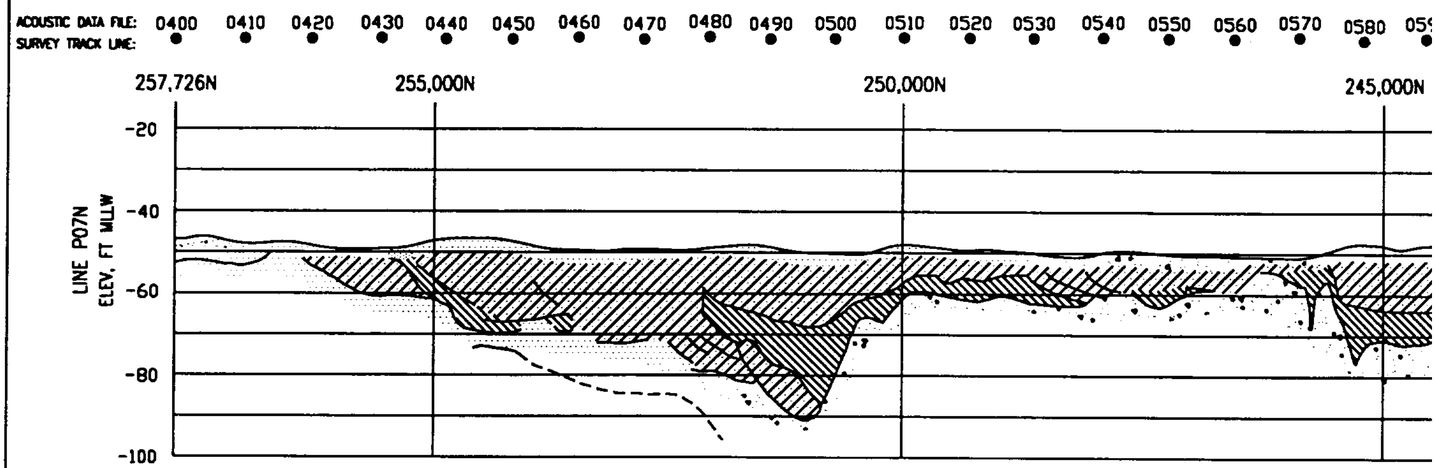
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P06N-S

FILE NO. P06N-S.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 16



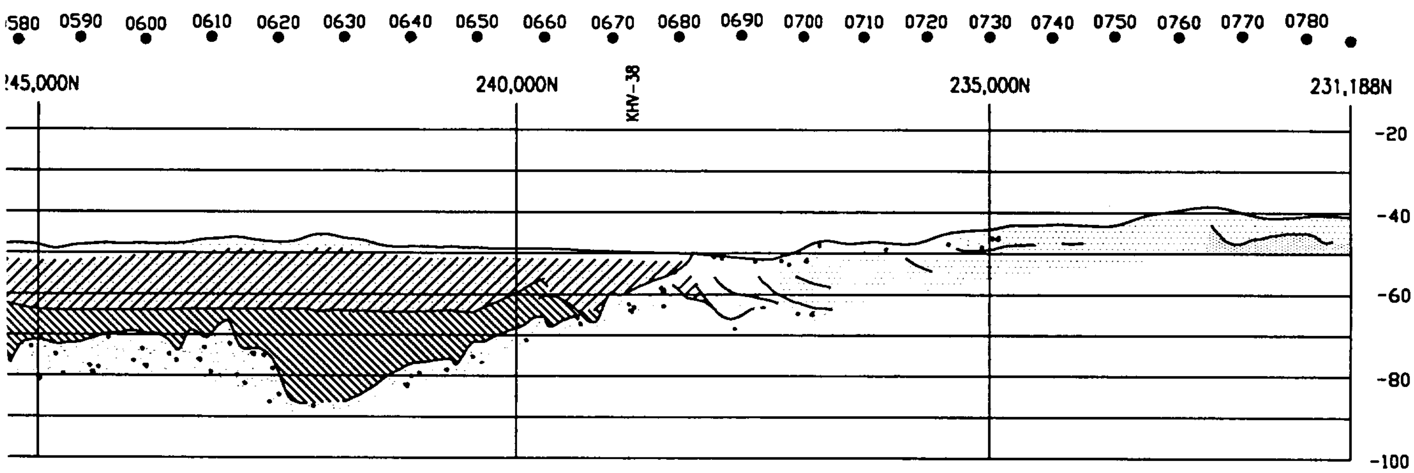
DELAWARE COAST SEDI		
Hatch Pattern	Density gm/cc	Mean Gr Size, Φ
	1.0 - 1.4	Outside M Boundar
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.
	1.8 - 2.0	2.2 - 1
	2.0 - 2.2	1.2 - (
	> 2.2	< 0

NOTES

• DATA BASEMENT DEFINED BY

SCALE

0 1000



SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

EFINED BY BOTTOM OF HATCHING

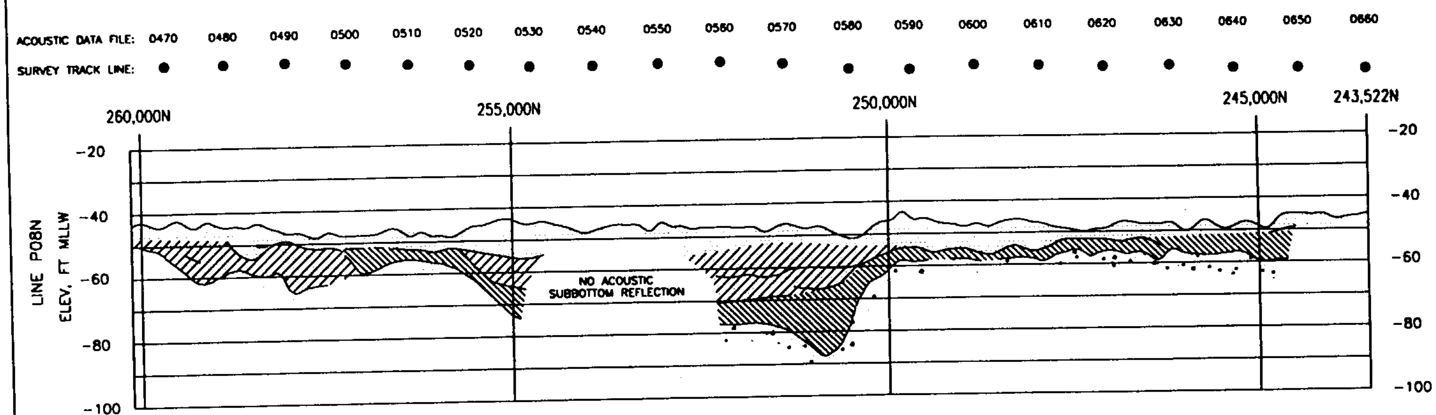
SCALE
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P07N-S

FILE NO. P07N-S.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 17



DATA QUALITY FOR LINE P08N POOR.
INTERPRETATIONS FORMULATED FROM SURROUNDING PROFILE LINES.

DELAWARE COAST SEDIMENT DESCRIPTION			
Hatch Pattern	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

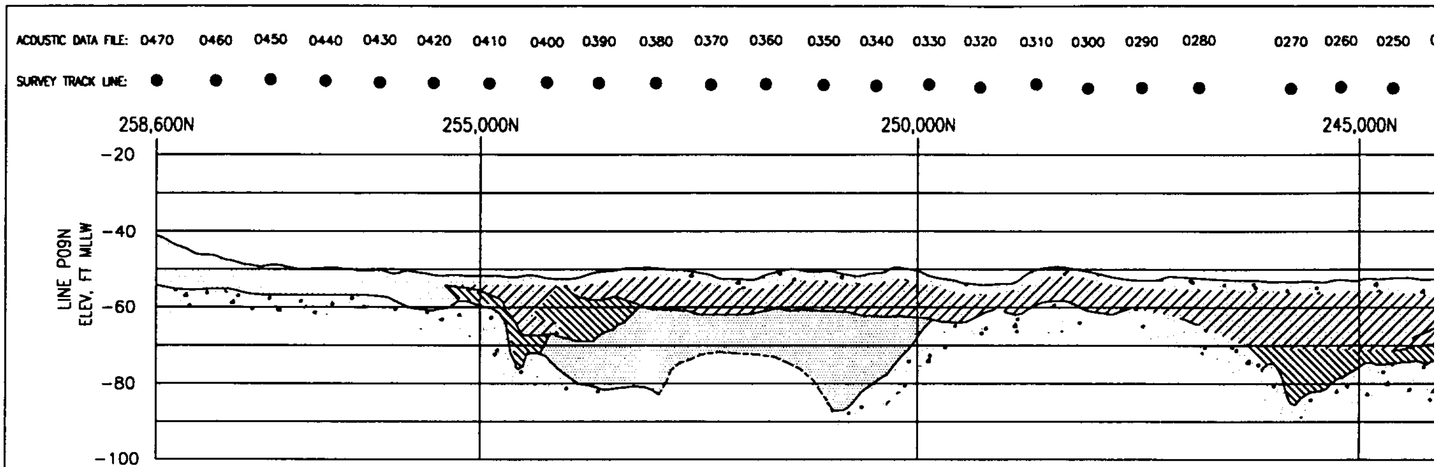
- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

SCALE
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P08N-S

FILE NAME: P08N-S
SCALE: 1" = 1000' DATE: AUGUST 8, 1995 PLATE 18



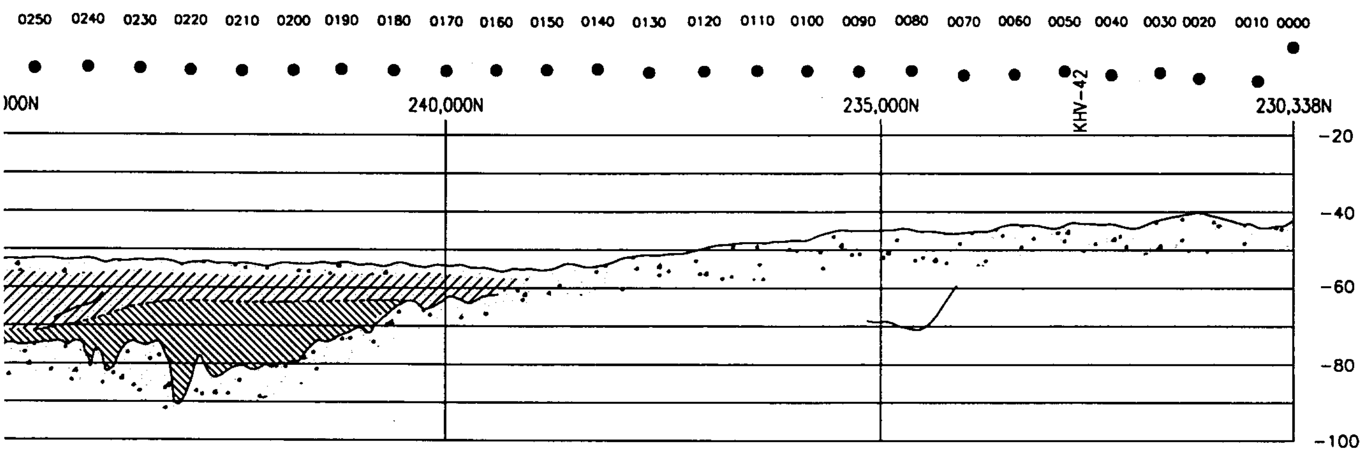
DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Bound
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	<

NOTE

- DATA BASEMENT DEFINED

SCALE

0 1000



T SEDIMENT DESCRIPTION	
Mean Grain Size, ϕ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

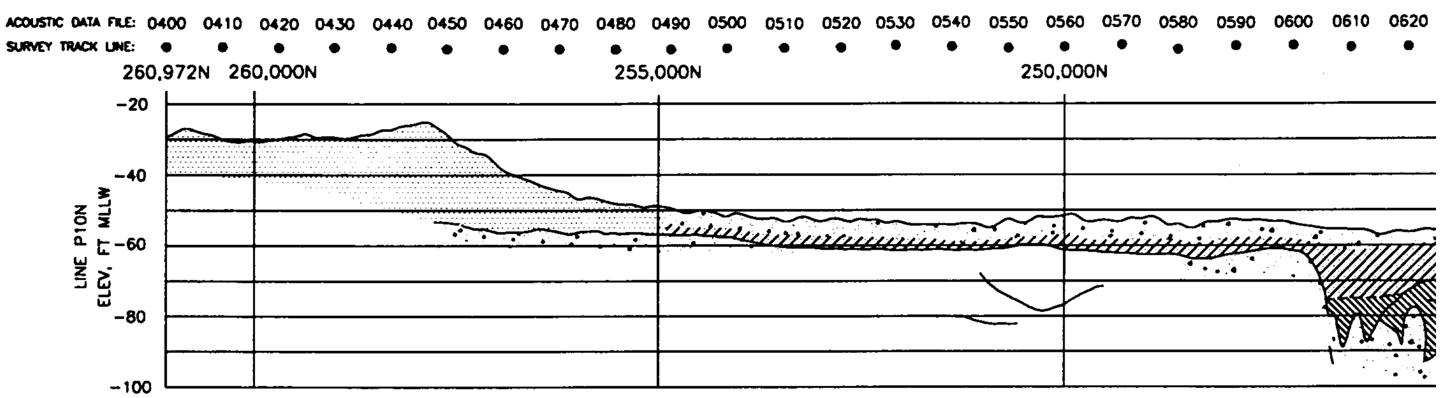
T DEFINED BY BOTTOM OF HATCHING

SCALE
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P09N-S

FILE NAME: P09N-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 19



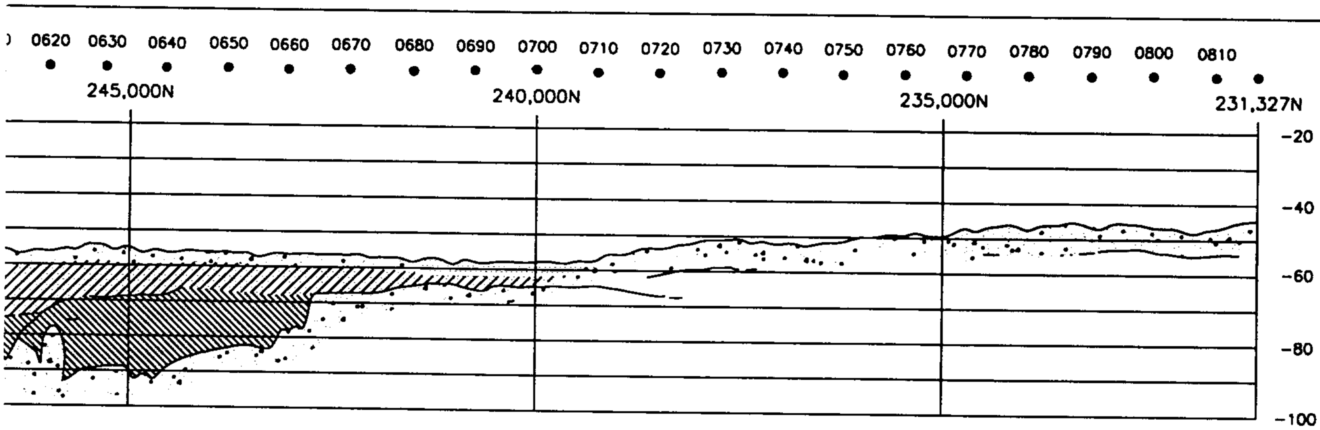
DELAWARE COAST S		
Hatch Pattern	Density gm/cc	Me Siz
	1.0 - 1.4	Outs B
	1.4 - 1.6	
	1.6 - 1.8	4
	1.8 - 2.0	2.
	2.0 - 2.2	1.
	> 2.2	

NO

• DATA BASEMENT DEFINED I

SCA

0 10



)AST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

DEFINED BY BOTTOM OF HATCHING

SCALE

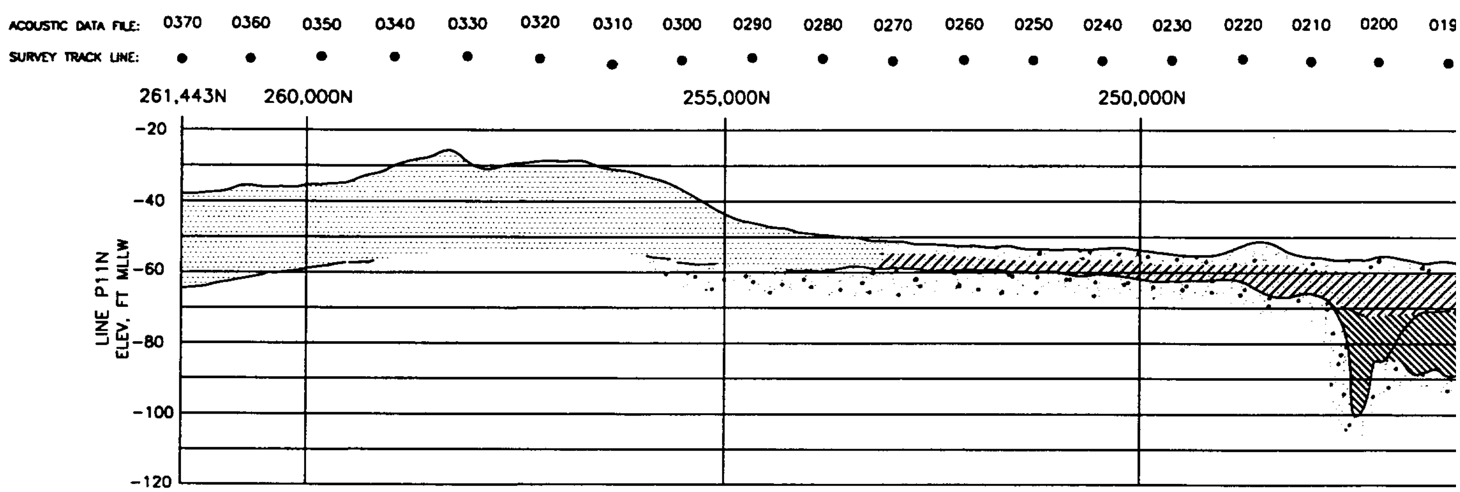
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P10N-S

FILE NAME: P10N-S.DWG

SCALE: 1"=1000' DATE: AUGUST 8, 1995 PLATE 20



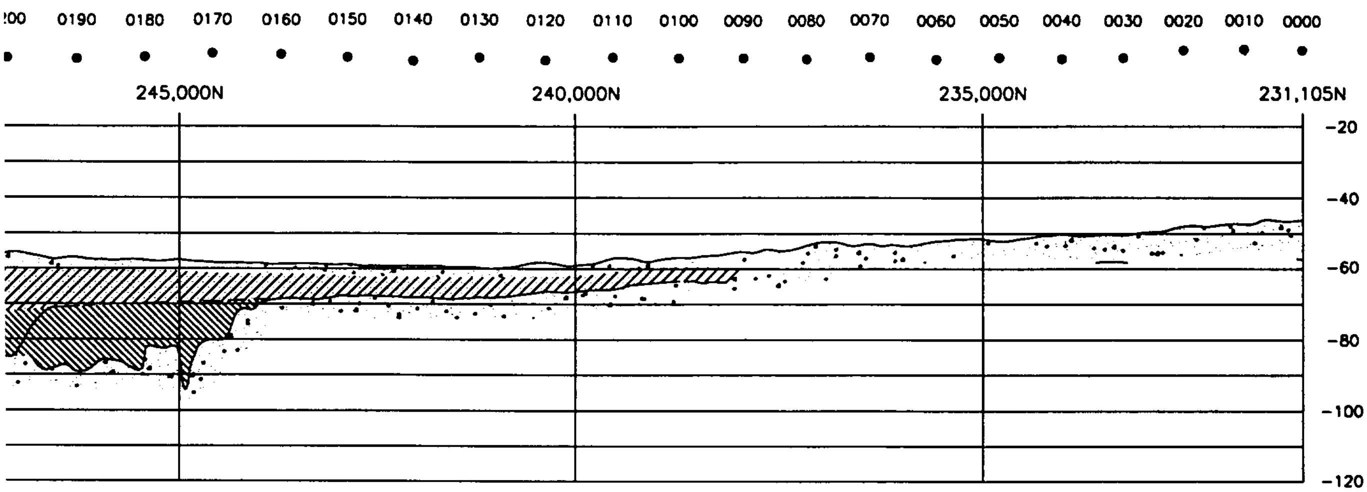
DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Bound
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	< (

NOTE

- DATA BASEMENT DEFINED BY

SCALE

0 1000



.ST SEDIMENT DESCRIPTION		
	Mean Grain Size, ϕ m	Basic Soil Description
	Outside Model Boundary	Soft Muds, Clays
	> 4	Clays, Silts, Sandy Silts
	4 - 2.2	Clayey Sands, Silty Silts
	2.2 - 1.2	Fine Sands
	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

DEFINED BY BOTTOM OF HATCHING

SCALE

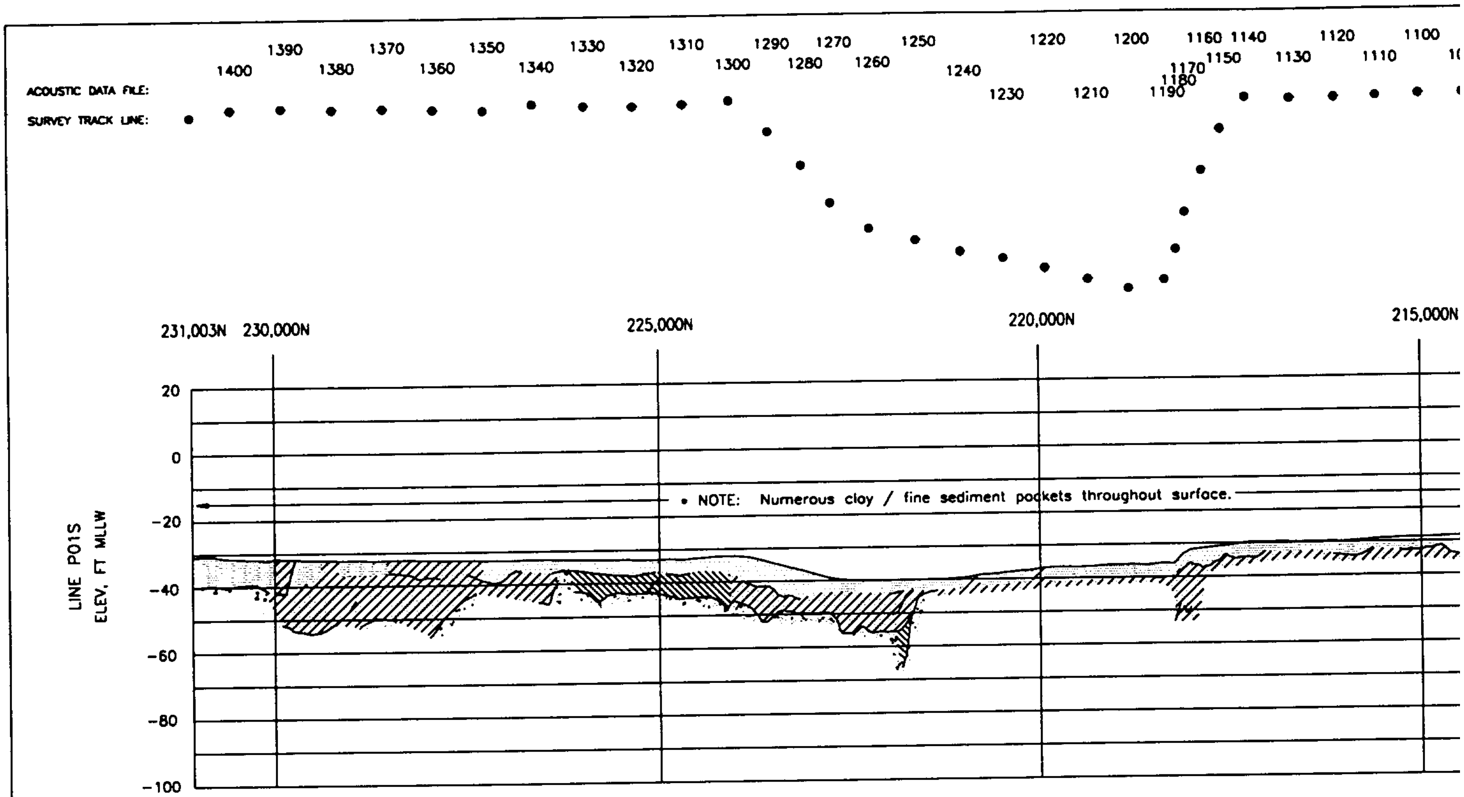
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P11N-S

FILE NAME: P11N-S.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 21



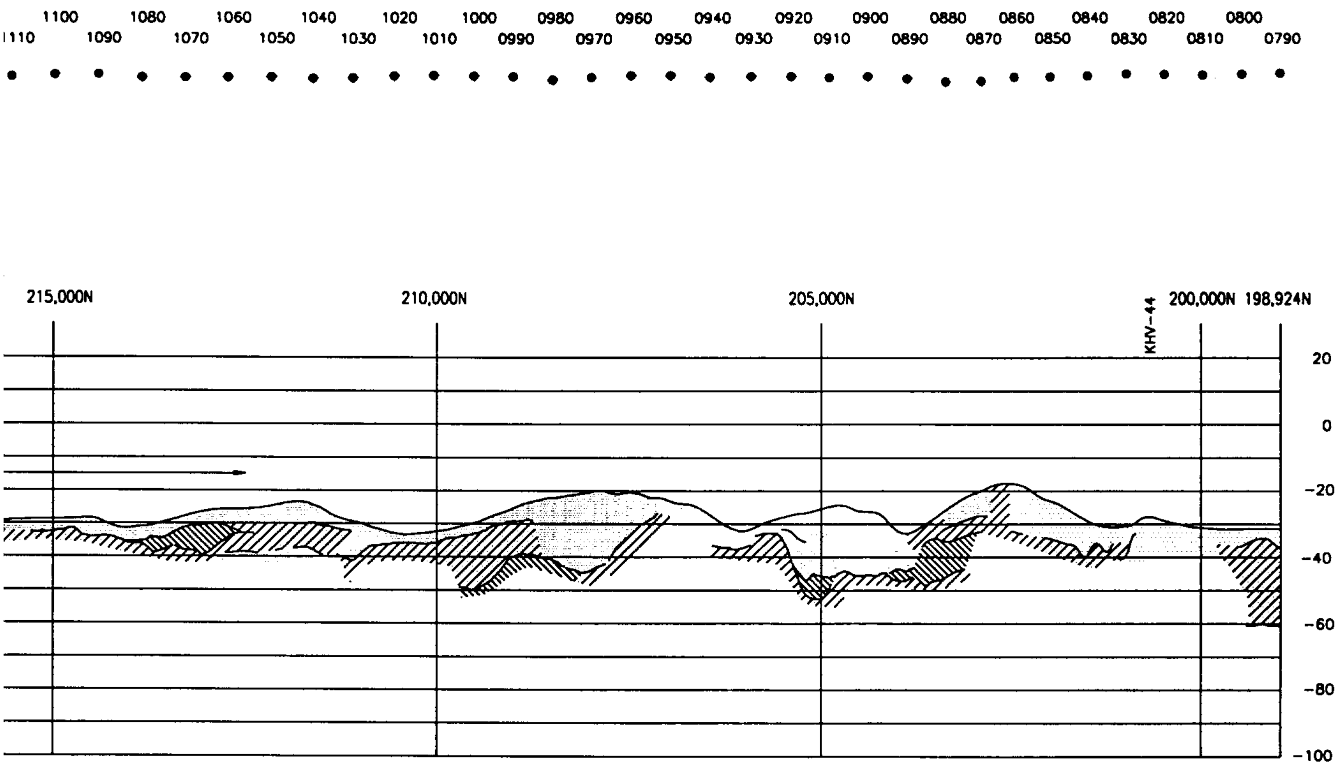
DELAWARE COAST SEDIME		
Hatch Pattern	Density gm/cc	Mean Grai Size, Φ m
	1.0 - 1.4	Outside Mod Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	< 0

NOTES

• DATA BASEMENT DEFINED BY BO

SCALE

0 1000



T SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

FINED BY BOTTOM OF HATCHING

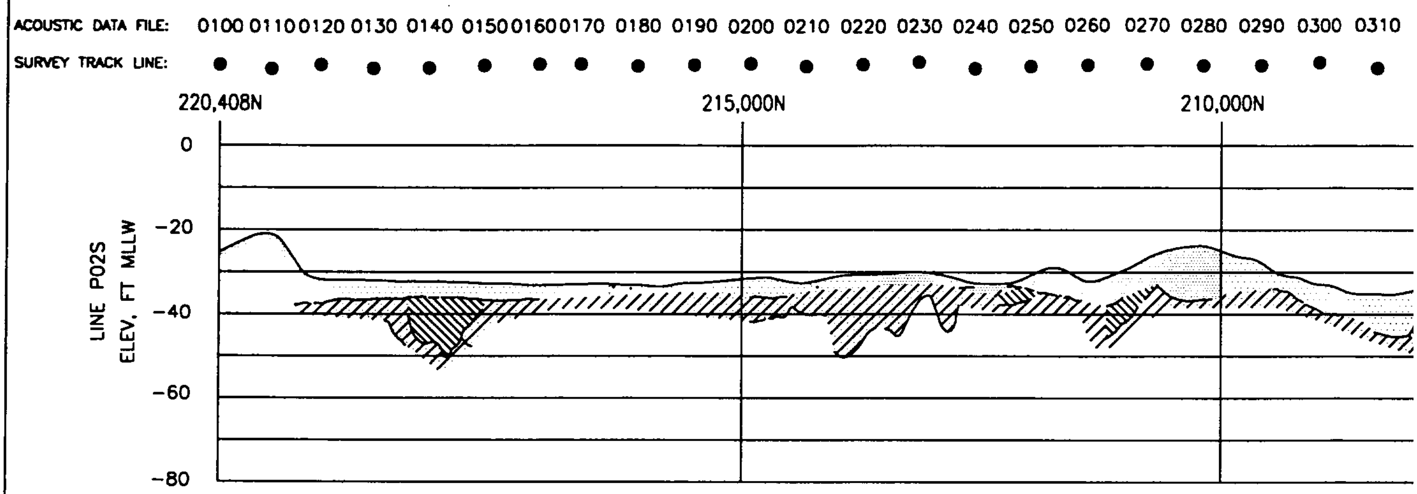
SCALE

1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P01S-N

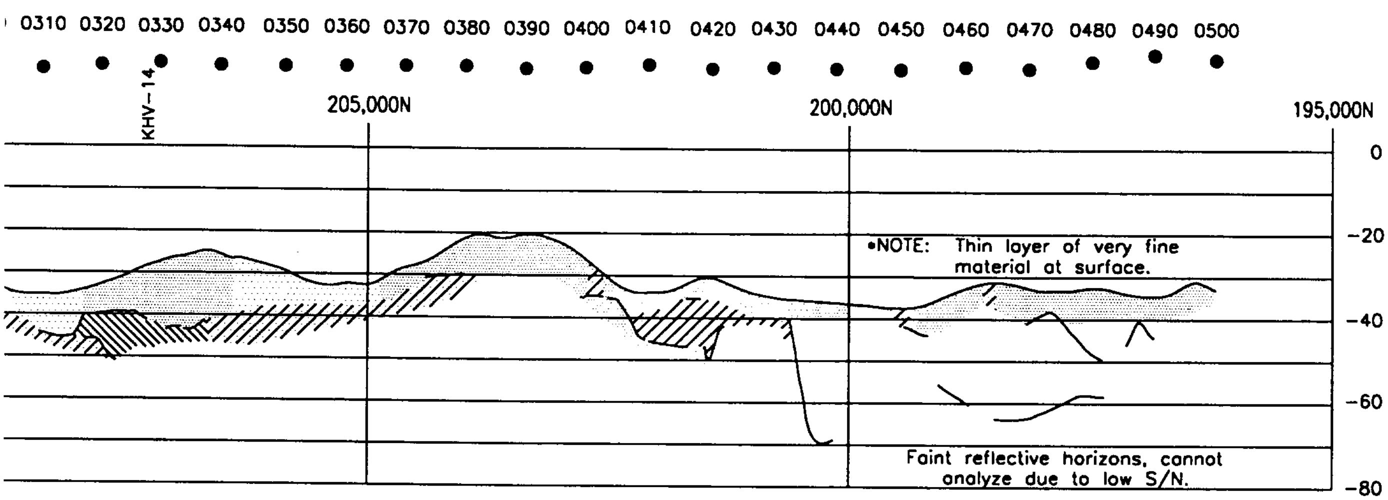
FILE NAME: P01S-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 22



DELAWARE COAST	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMENT DEFINE

0



OAST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

NT DEFINED BY BOTTOM OF HATCHING

SCALE

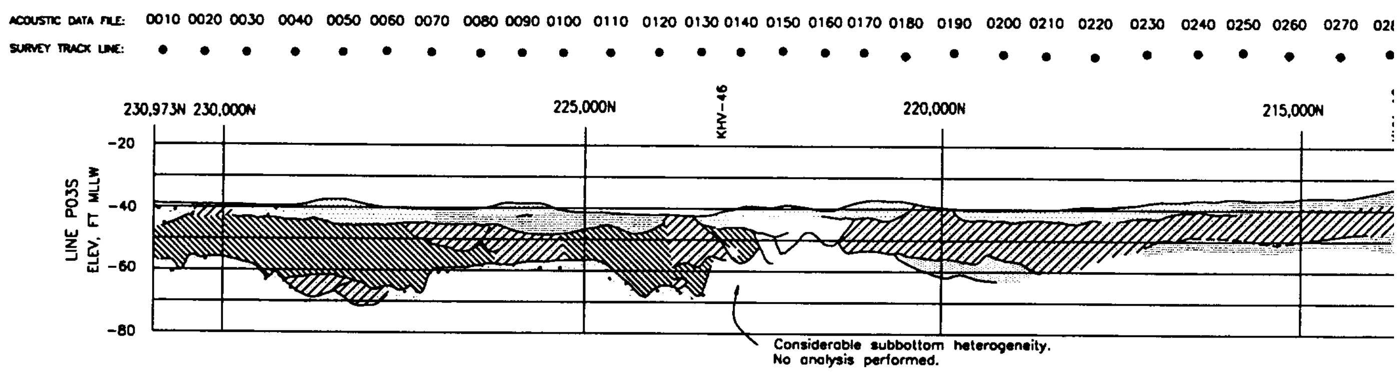
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P02S-N

FILE NAME: P02S-N.DWG

SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 23



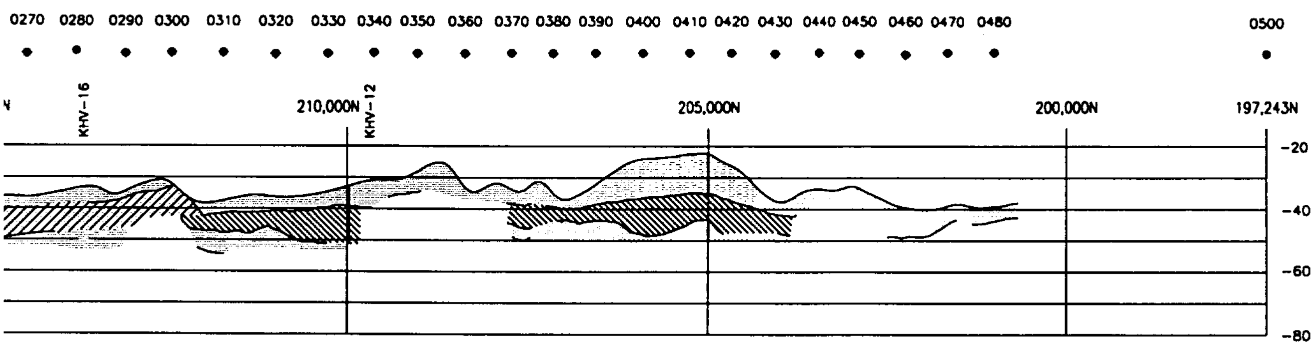
DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	<

NOT

- DATA BASEMENT DEFINED BY

SCAL

0 100



)AST SEDIMENT DESCRIPTION		
	Mean Grain Size, Φ m	Basic Soil Description
	Outside Model Boundary	Soft Muds, Clays
	> 4	Clays, Silts, Sandy Silts
	4 - 2.2	Clayey Sands, Silty Silts
	2.2 - 1.2	Fine Sands
	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

'T DEFINED BY BOTTOM OF HATCHING

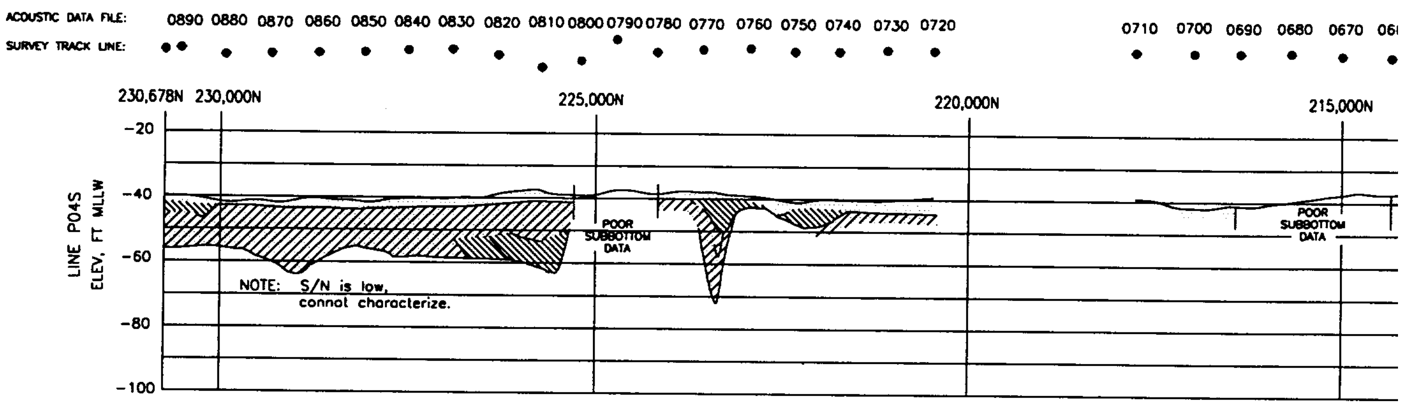
SCALE

) 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P03S-N

FILE NAME: P03S-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 8, 1995	PLATE 24



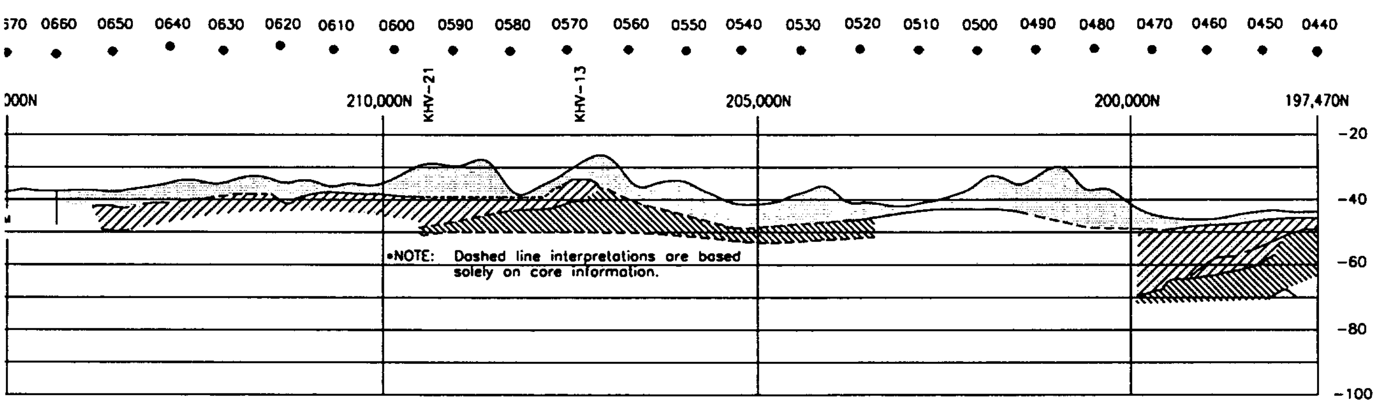
DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mear Size
	1.0 - 1.4	Outsid Bou
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2
	2.0 - 2.2	1.2
	> 2.2	<

NO

• DATA BASEMENT DEFINED

SC

0 10



ST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

' DEFINED BY BOTTOM OF HATCHING

SCALE

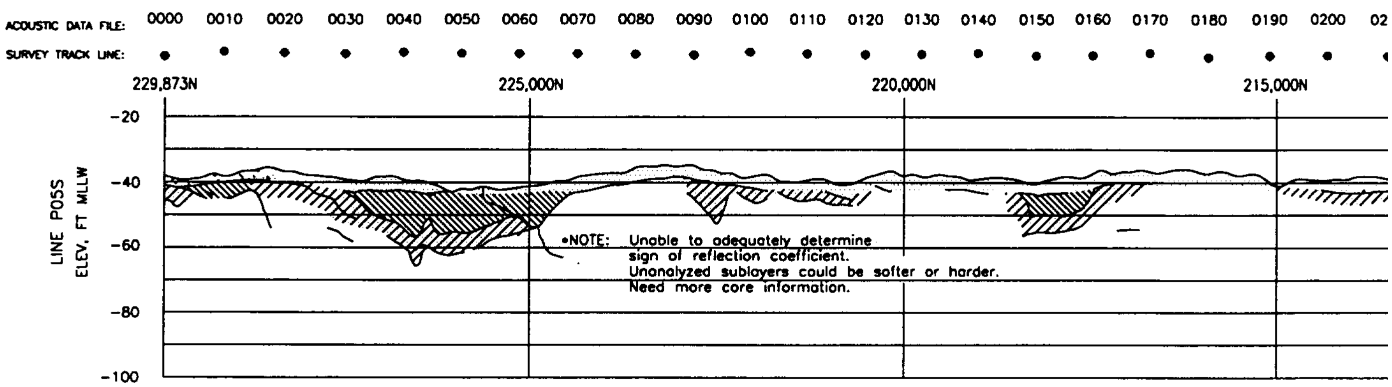
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P04S-N

FILE NAME: P04S-N.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 25



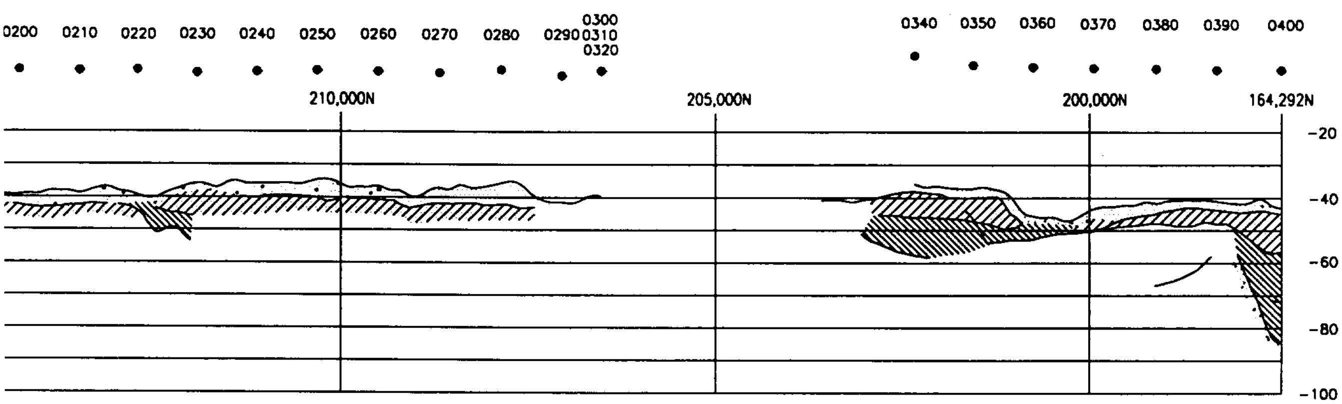
DELAWARE COAST SEDI		
Hatch Pattern	Density gm/cc	Mean G Size, ϕ
	1.0 - 1.4	Outside M Bounda
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	< 0

NOTES

- DATA BASEMENT DEFINED BY BO

SCALE

0 1000



ST SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

FINED BY BOTTOM OF HATCHING

SCALE

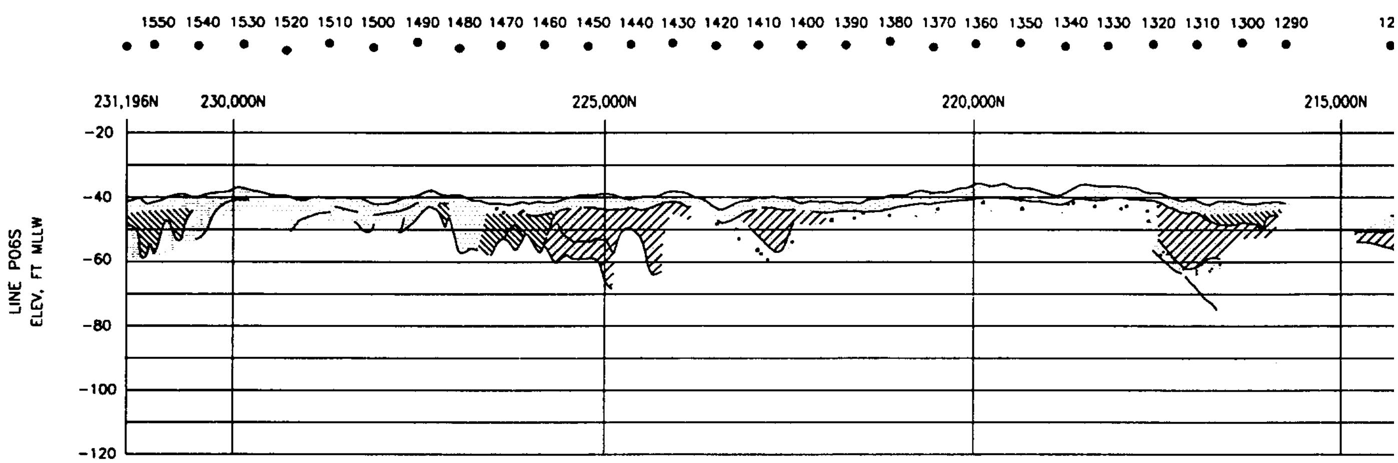
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P05S-N

FILE NAME: P05S-N.DWG

SCALE: 1" = 1000' | DATE: AUGUST 8, 1995 | PLATE 26



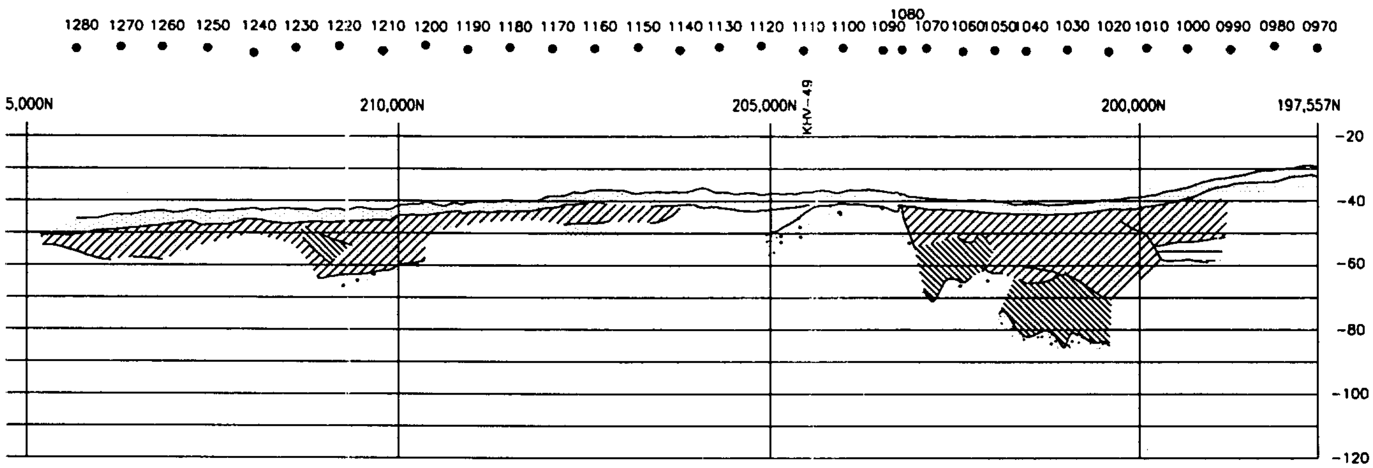
DELAWARE COAST SEDI		
Hatch Pattern	Density gm/cc	Mean Gr Size, Φ
	1.0 - 1.4	Outside M Bounda
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.
	1.8 - 2.0	2.2 - 1
	2.0 - 2.2	1.2 -
	> 2.2	< 0

NOTES

- DATA BASEMENT DEFINED BY B

SCALE

0 1000



T SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

EFINED BY BOTTOM OF HATCHING

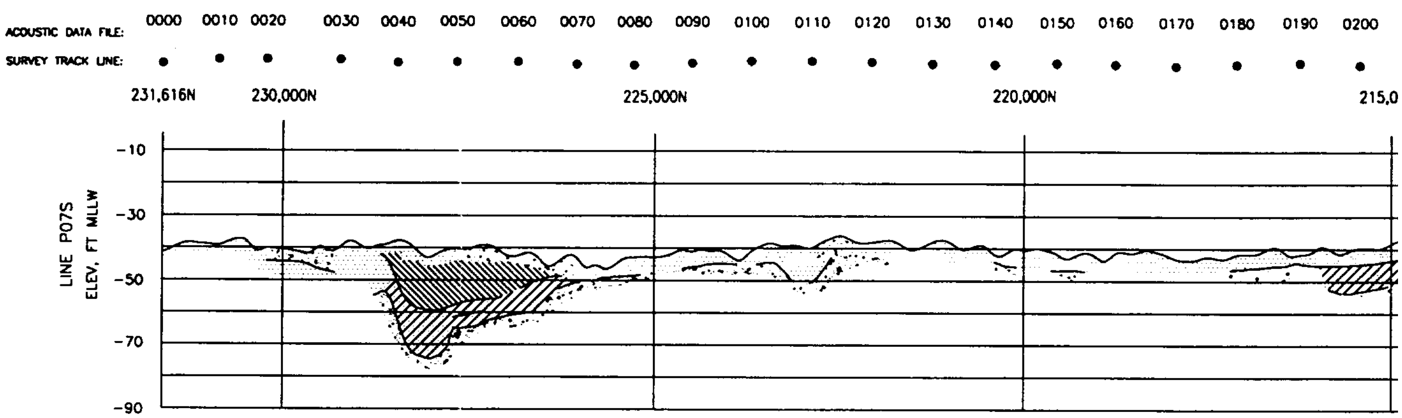
SCALE
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P06S-N

FILE NAME: P06S-N.DWG

SCALE: 1"=1000' | DATE: AUGUST 8, 1995 | PLATE 27



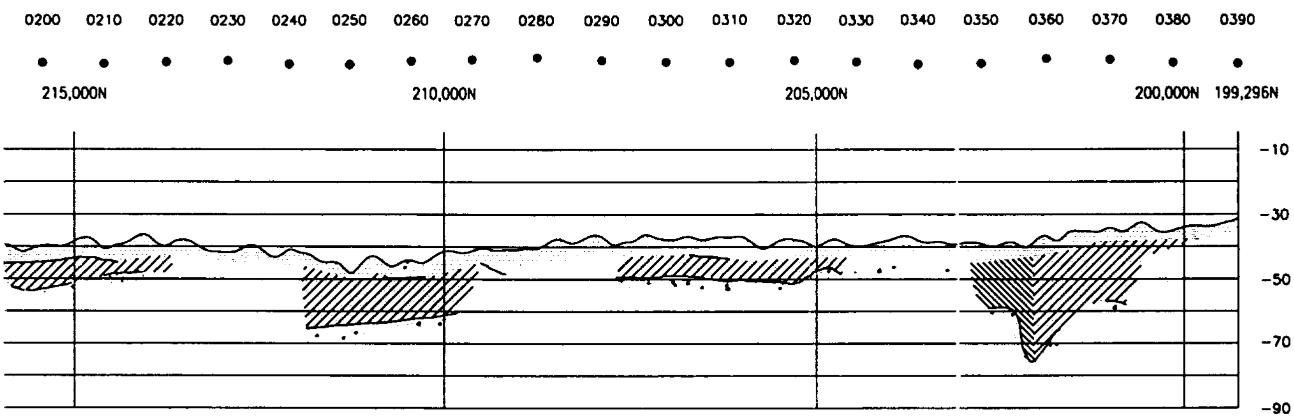
DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mean Size
	1.0 - 1.4	Outsid Bou
	1.4 - 1.6	>
	1.6 - 1.8	4
	1.8 - 2.0	2.2
	2.0 - 2.2	1.2
	> 2.2	<

NOT

• DATA BASEMENT DEFINED B

SCA

0 100



)AST SEDIMENT DESCRIPTION

	Mean Grain Size, Φ m	Basic Soil Description
	Outside Model Boundary	Soft Muds, Clays
	> 4	Clays, Silts, Sandy Silts
	4 - 2.2	Clayey Sands, Silty Silts
	2.2 - 1.2	Fine Sands
	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

NT DEFINED BY BOTTOM OF HATCHING

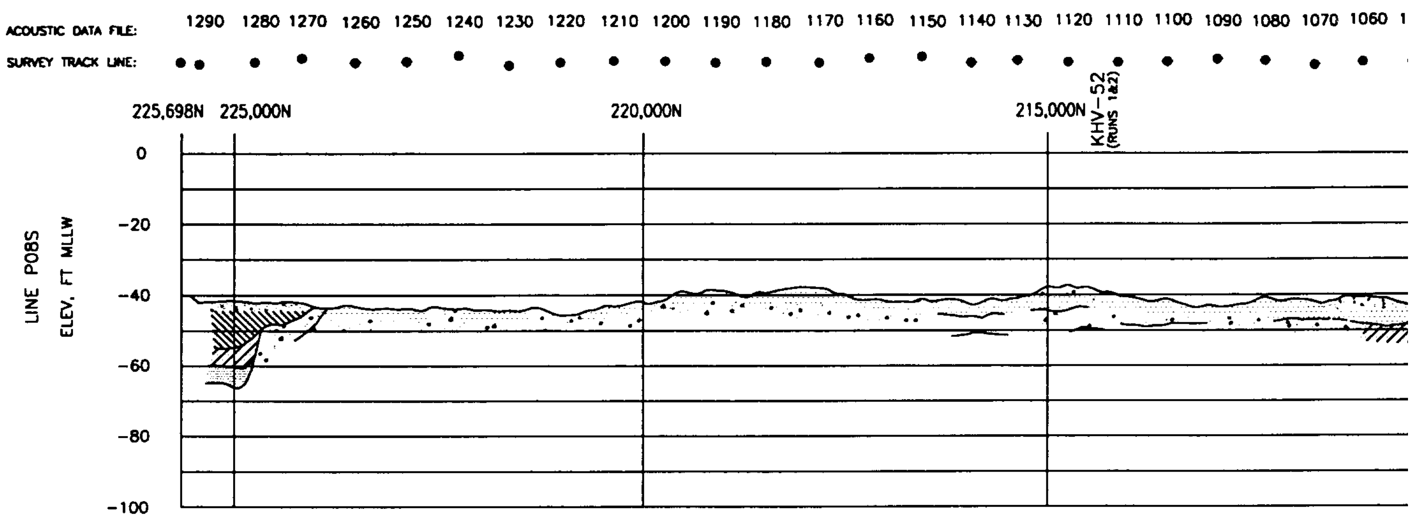
SCALE

) 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P07S-N

FILE NAME: P07S-N.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 9, 1995	PLATE 28



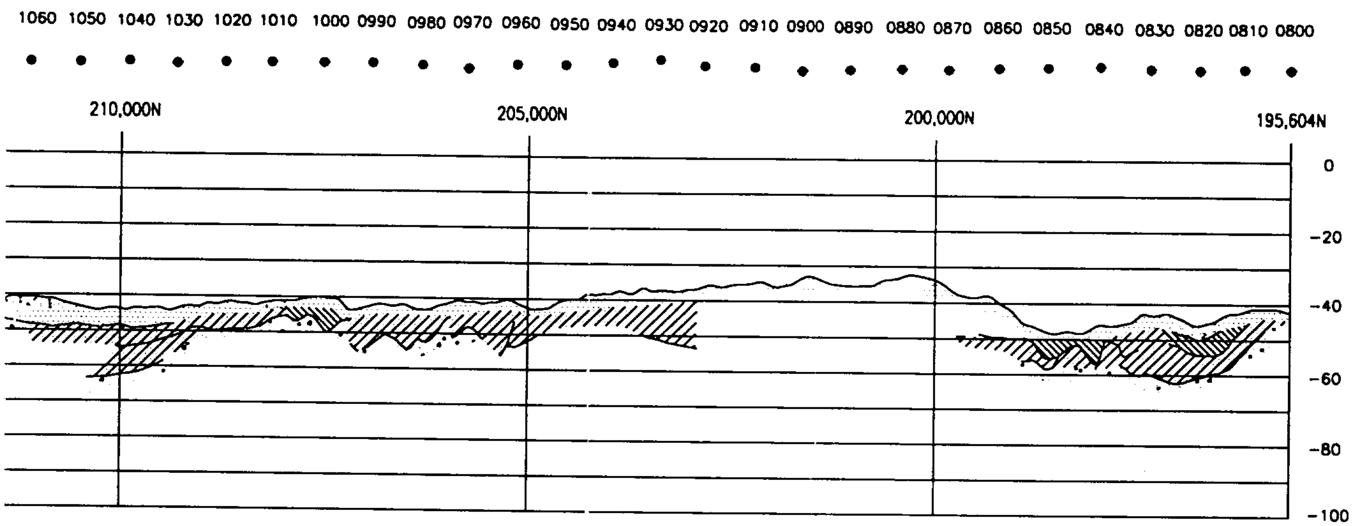
DELAWARE COAST SEDIM		
Hatch Pattern	Density gm/cc	Mean Gr Size, Φ
	1.0 - 1.4	Outside Mo Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.
	2.0 - 2.2	1.2 - 0
	> 2.2	< 0

NOTES

• DATA BASEMENT DEFINED BY BO

SCALE

0 1000



SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

ED BY BOTTOM OF HATCHING

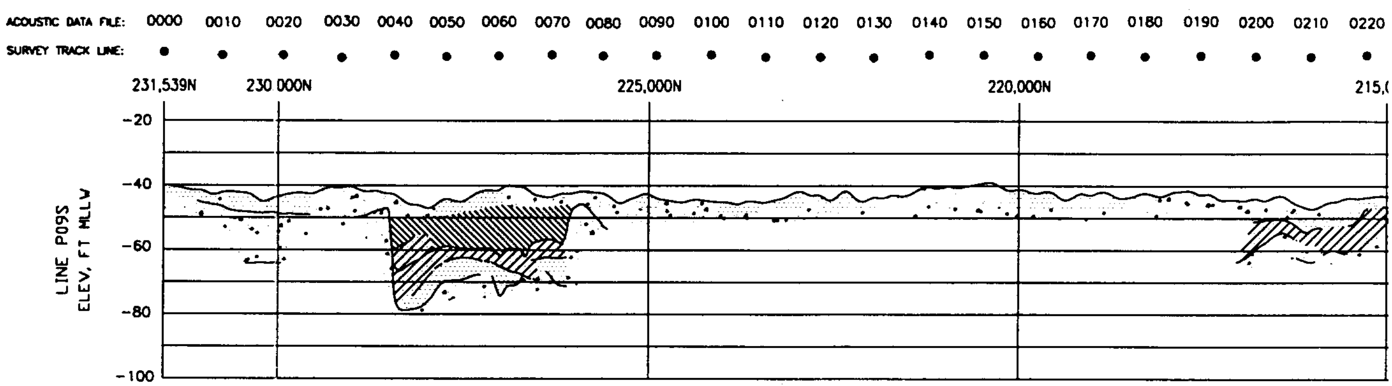
SCALE

1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P08S-N

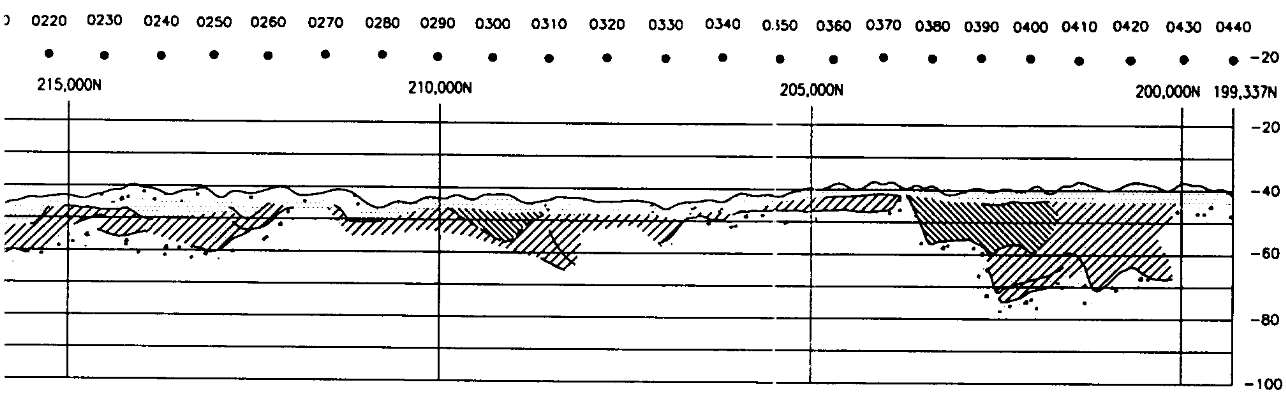
FILE NAME: P08S-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 29



DELAWARE COAST S		
Hatch Pattern	Density gm/cc	Me Si
	1.0 - 1.4	Outs B
	1.4 - 1.6	
	1.6 - 1.8	4
	1.8 - 2.0	2.
	2.0 - 2.2	1
	> 2.2	

• DATA BASEMENT DEFINE

0



)AST SEDIMENT DESCRIPTION

	Mean Grain Size, Φm	Basic Soil Description
	Outside Model Boundary	Soft Muds, Clays
	> 4	Clays, Silts, Sandy Silts
	4 - 2.2	Clayey Sands, Silty Silts
	2.2 - 1.2	Fine Sands
	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

ENT DEFINED BY BOTTOM OF HATCHING

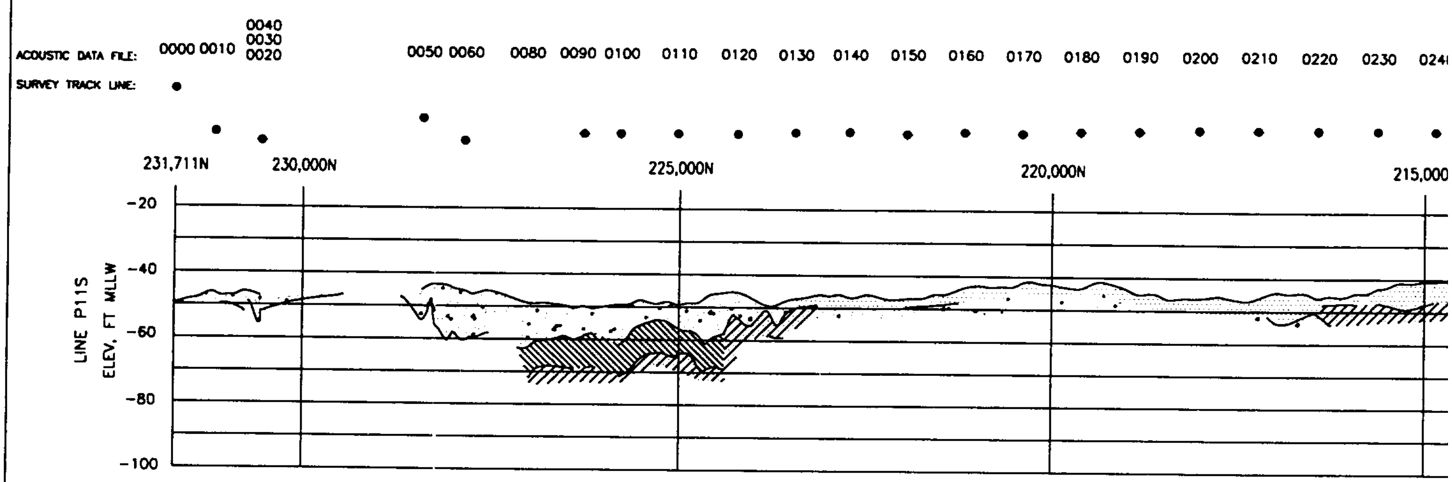
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P09S-N

FILE NAME: P09S-N.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 9, 1995	PLATE 30

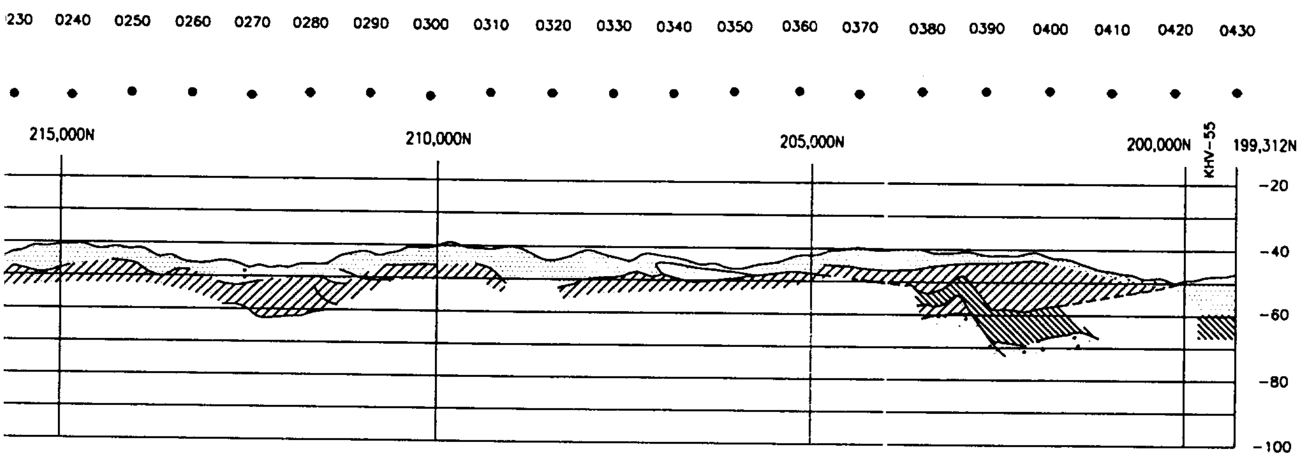


DELAWARE COAST SEDIM		
Hatch Pattern	Density gm/cc	Mean Grai Size, Φ n
	1.0 - 1.4	Outside Mod Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	< 0

NOTES

- DATA BASEMENT DEFINED BY BOT

SCALE
0 1000



T SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

FINED BY BOTTOM OF HATCHING

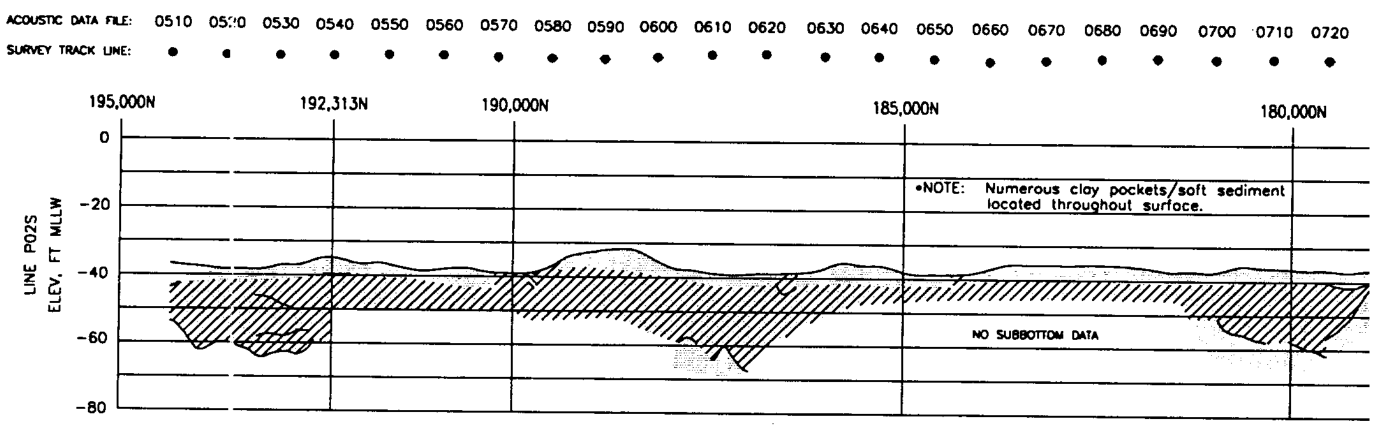
SCALE

1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

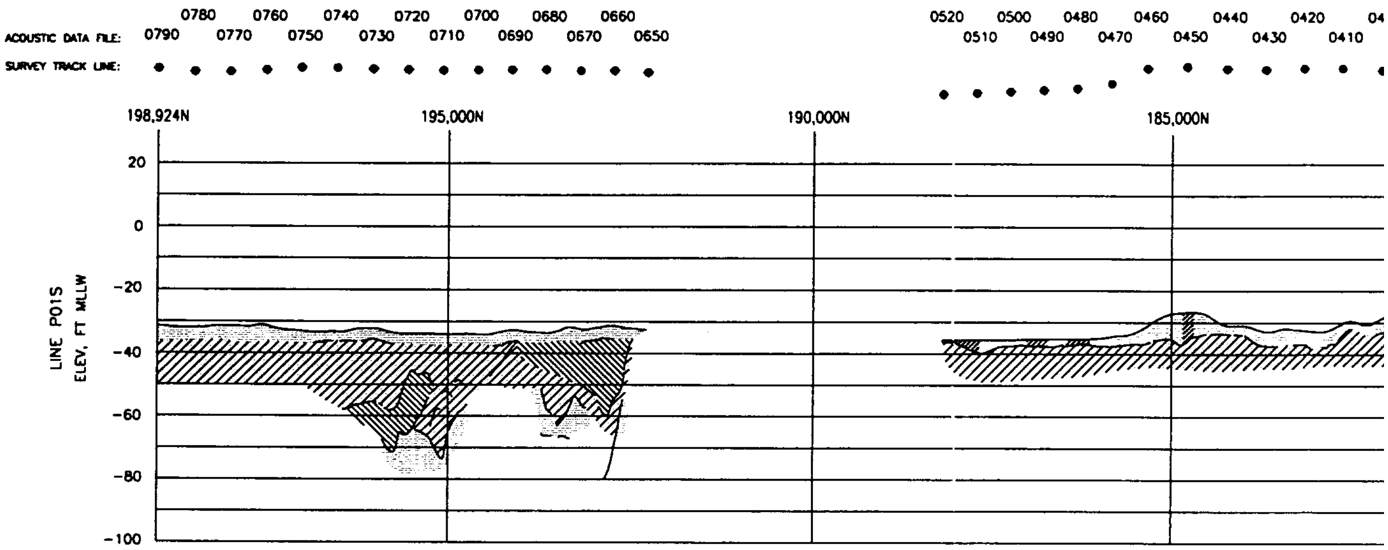
DELAWARE COAST
LINE P11S-N

FILE NAME: P11S-N.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 31



DELAWARE C	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMEN



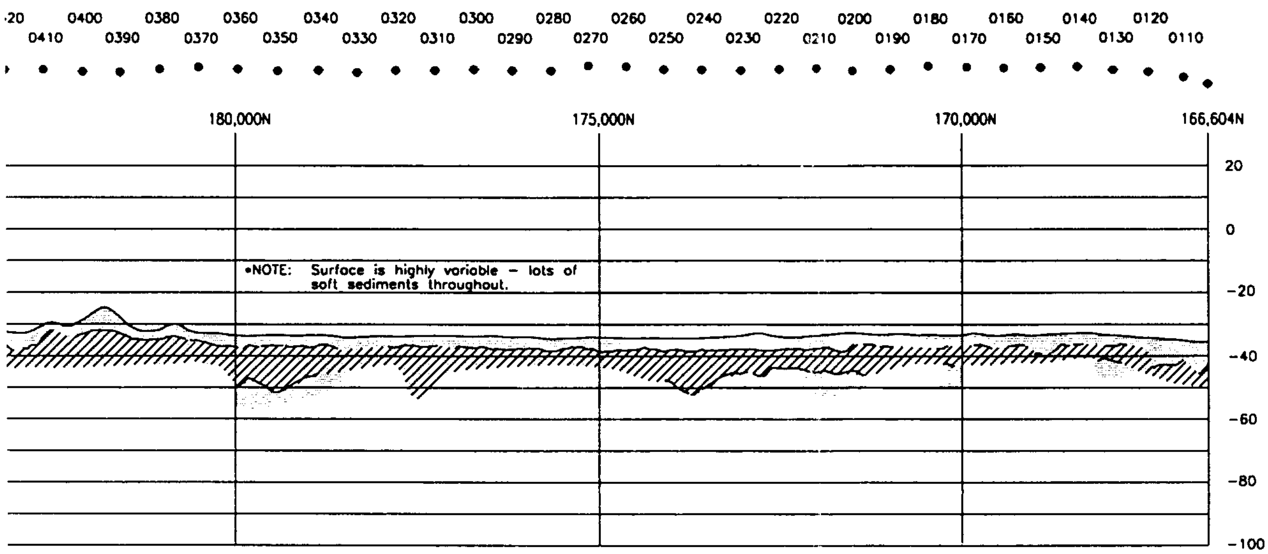
DELAWARE COAST SEDIME		
Hatch Pattern	Density gm/cc	Mean Grai Size, ɸ m
	1.0 - 1.4	Outside Mode Boundary
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2.2
	1.8 - 2.0	2.2 - 1.2
	2.0 - 2.2	1.2 - 0
	> 2.2	< 0

NOTES

- DATA BASEMENT DEFINED BY BOT

SCALE

0 1000



SEDIMENT DESCRIPTION	
Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

·INED BY BOTTOM OF HATCHING

SCALE

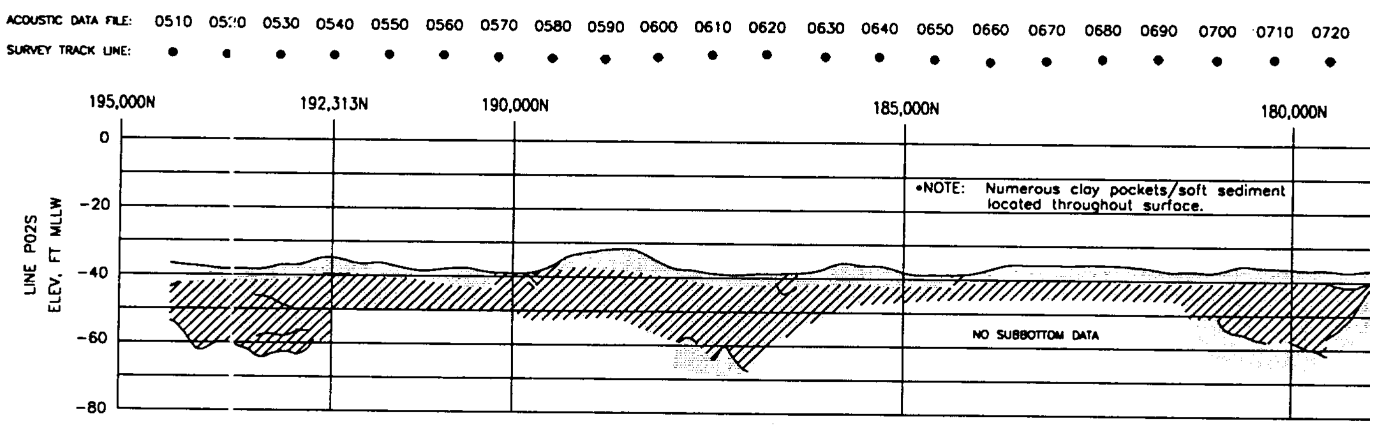
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P01S-S

FILE NAME: P01S-S.DWG

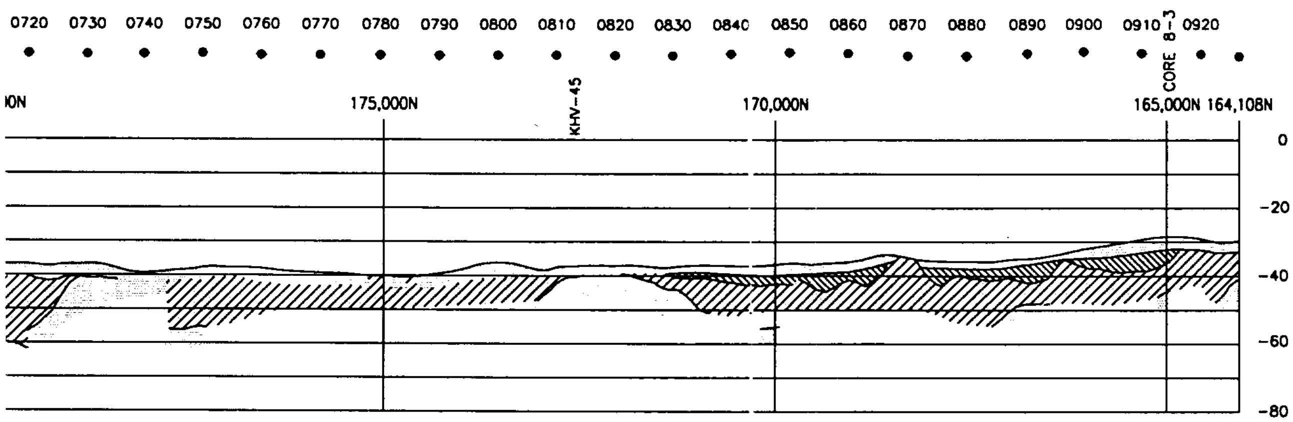
SCALE: 1"=1000' | DATE: AUGUST 9, 1995 | PLATE 32



DELAWARE C	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMEN

0



ARE COAST SEDIMENT DESCRIPTION

Density gm/cc	Mean Grain Size, ϕ m	Basic Soil Description
1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
1.8 - 2.0	2.2 - 1.2	Fine Sands
2.0 - 2.2	1.2 - 0	Medium Sands
> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

A BASEMENT DEFINED BY BOTTOM OF HATCHING

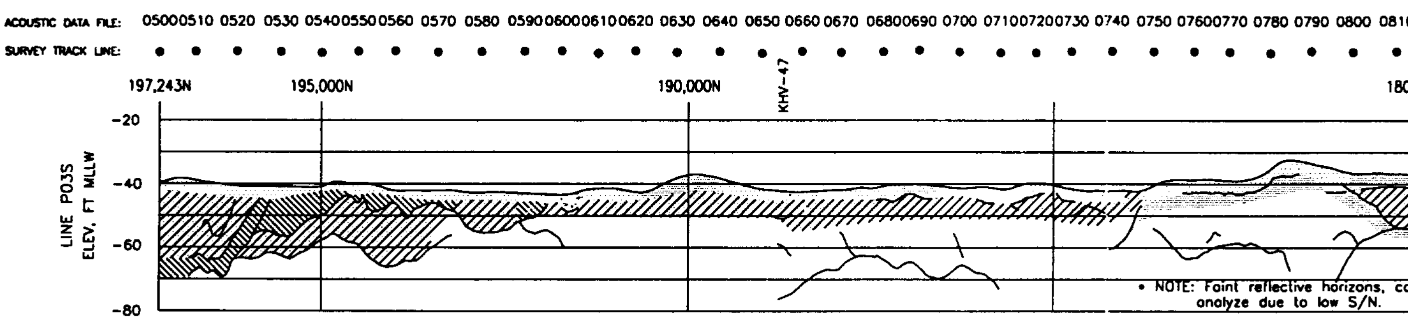
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P02S-S

FILE NAME: P02S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 33



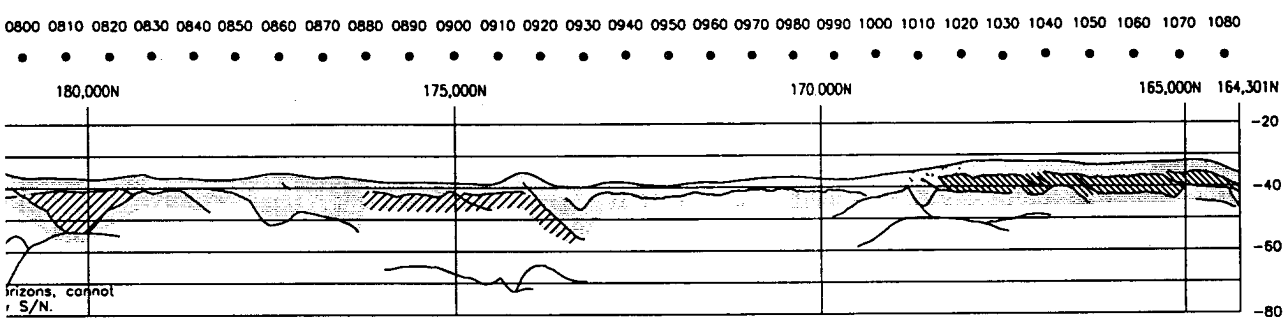
DELAWARE COAST SEDI		
Hatch Pattern	Density gm/cc	Mean G Size, ϕ
	1.0 - 1.4	Outside M Bounda
	1.4 - 1.6	> 4
	1.6 - 1.8	4 - 2
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2 -
	> 2.2	< 0

NOTES

• DATA BASEMENT DEFINED BY BO

SCALE

0 1000



ST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

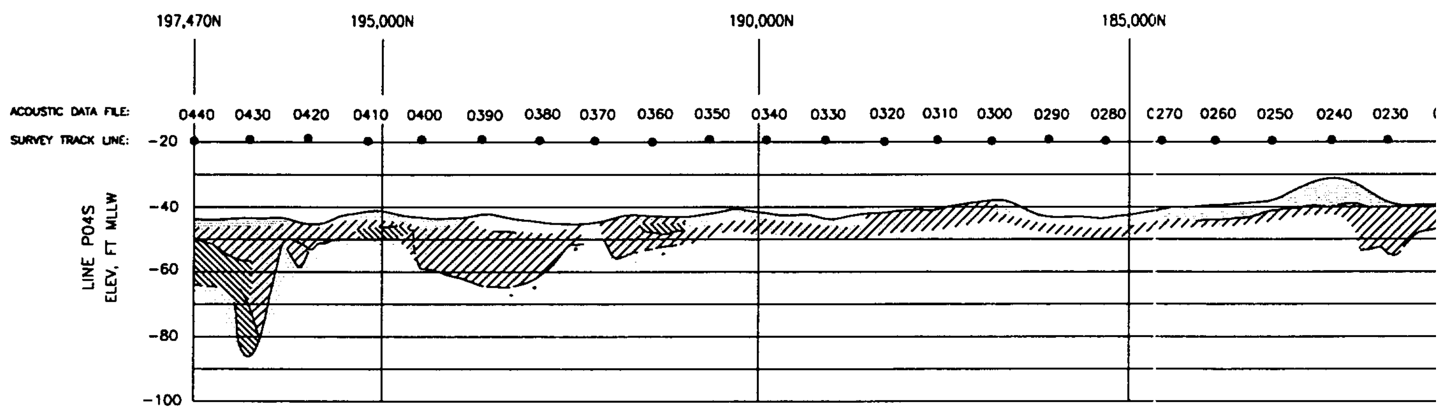
FINED BY BOTTOM OF HATCHING

SCALE
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P03S-S

FILE NAME: P03S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 34



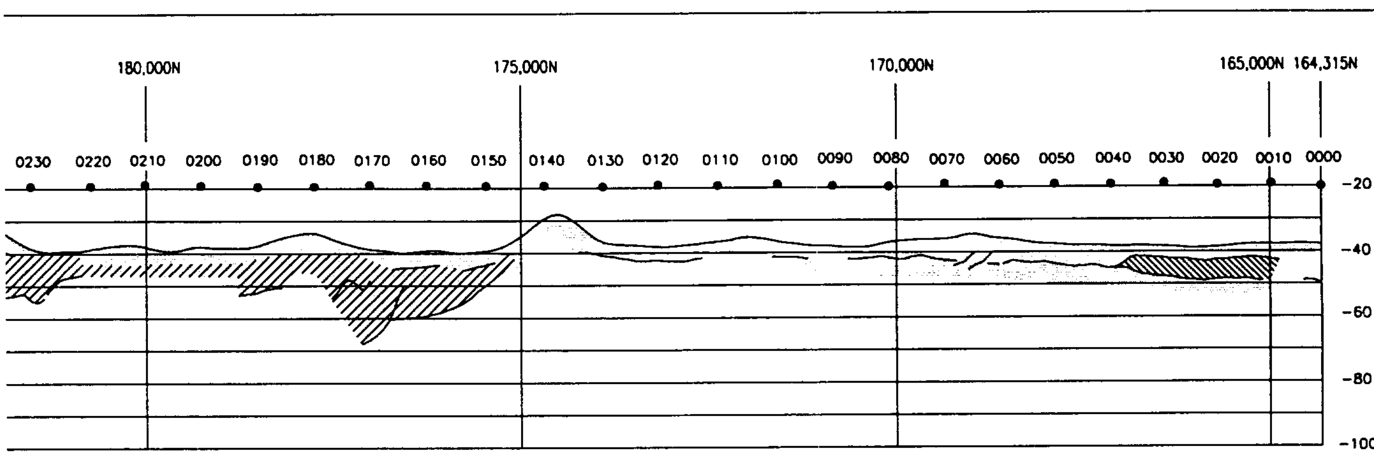
DELAWARE COAST SE		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	<

NOTE

• DATA BASEMENT DEFINED BY

SCAL

0 100



AST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

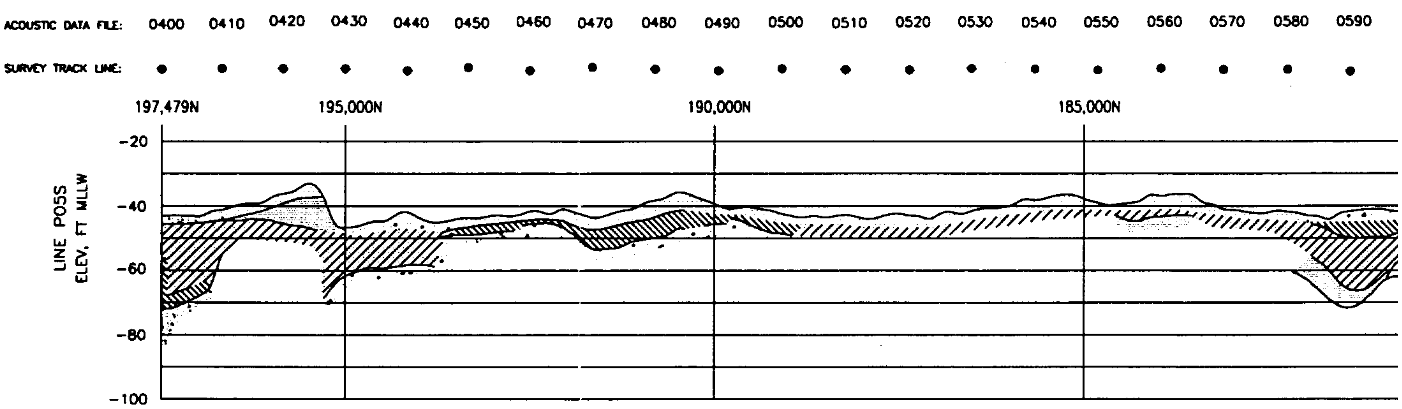
NOTES

DEFINED BY BOTTOM OF HATCHING

SCALE

1000 2000 FT

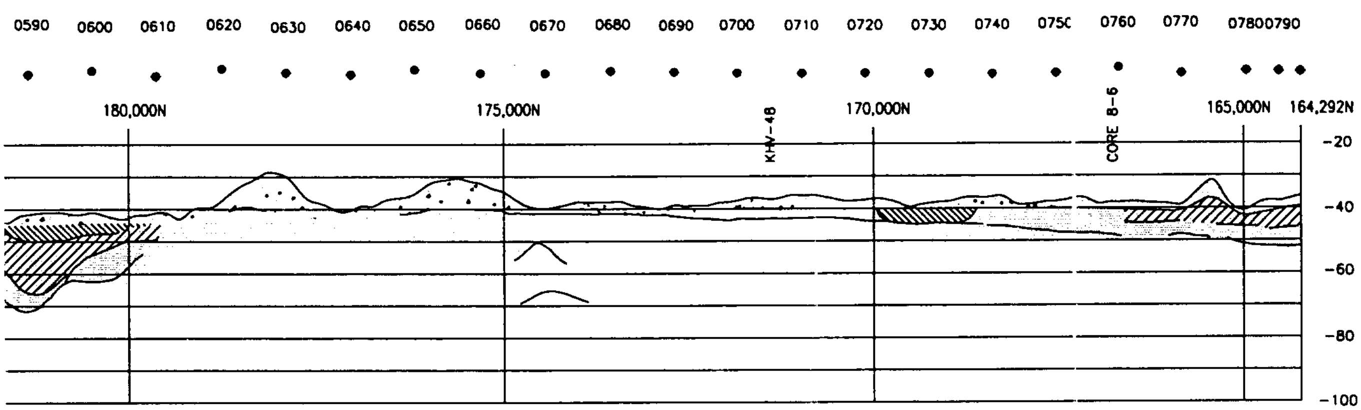
WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE COAST LINE P04S-S		
FILE NAME: P04S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 35



DELAWARE COAST	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMENT DEFI

0



COAST SEDIMENT DESCRIPTION		
;ity /cc	Mean Grain Size, Φ m	Basic Soil Description
1.4	Outside Model Boundary	Soft Muds, Clays
1.6	> 4	Clays, Silts, Sandy Silts
1.8	4 - 2.2	Clayey Sands, Silty Silts
2.0	2.2 - 1.2	Fine Sands
2.2	1.2 - 0	Medium Sands
.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

;EMENT DEFINED BY BOTTOM OF HATCHING

SCALE

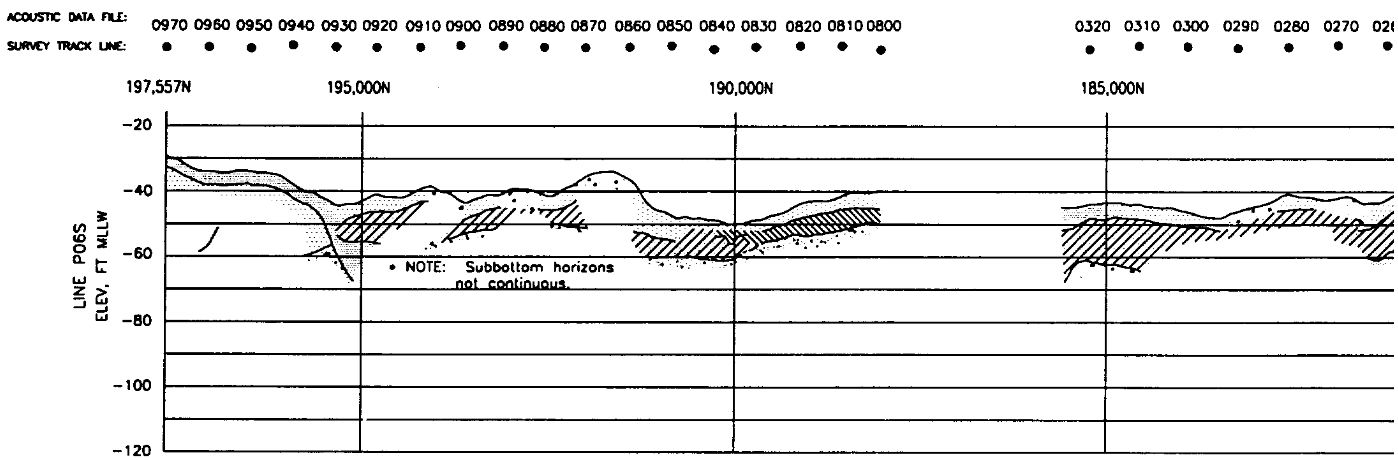
0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P05S-S

FILE NAME: P(5S-S.DWG

SCALE: 1"=10)0' | DATE: AUGUST 9, 1995 | PLATE 36



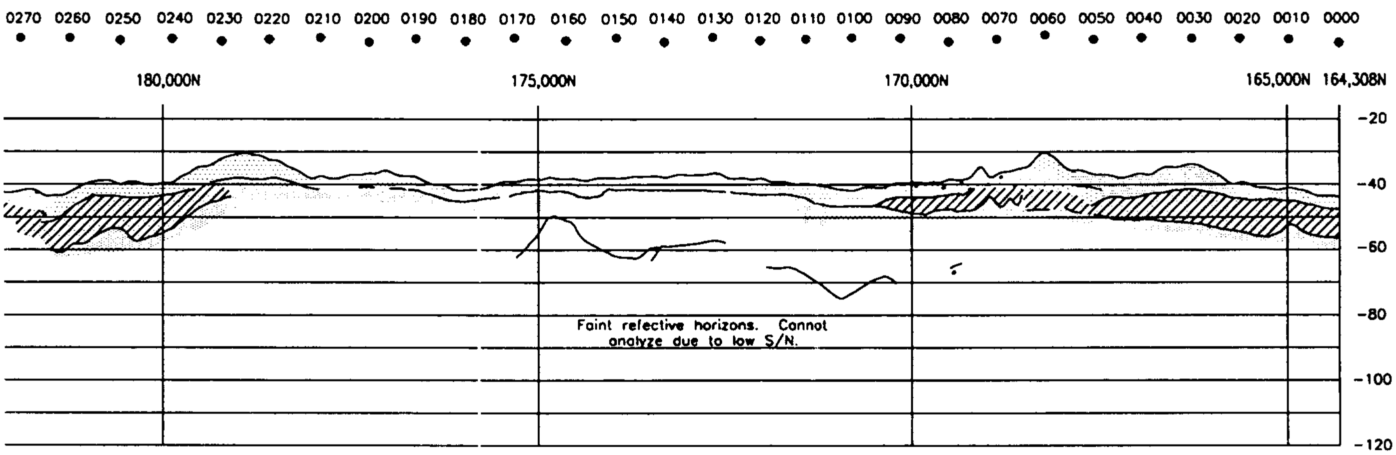
DELAWARE COAST SED		
Hatch Pattern	Density gm/cc	Mean Size,
	1.0 - 1.4	Outside Boun
	1.4 - 1.6	>
	1.6 - 1.8	4 -
	1.8 - 2.0	2.2 -
	2.0 - 2.2	1.2
	> 2.2	<

NOT

• DATA BASEMENT DEFINED B

SCAL

0 100



ST SEDIMENT DESCRIPTION		
	Mean Grain Size, Φ m	Basic Soil Description
	Outside Model Boundary	Soft Muds, Clays
	> 4	Clays, Silts, Sandy Silts
	4 - 2.2	Clayey Sands, Silty Silts
	2.2 - 1.2	Fine Sands
	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

[DEFINED BY BOTTOM OF HATCHING

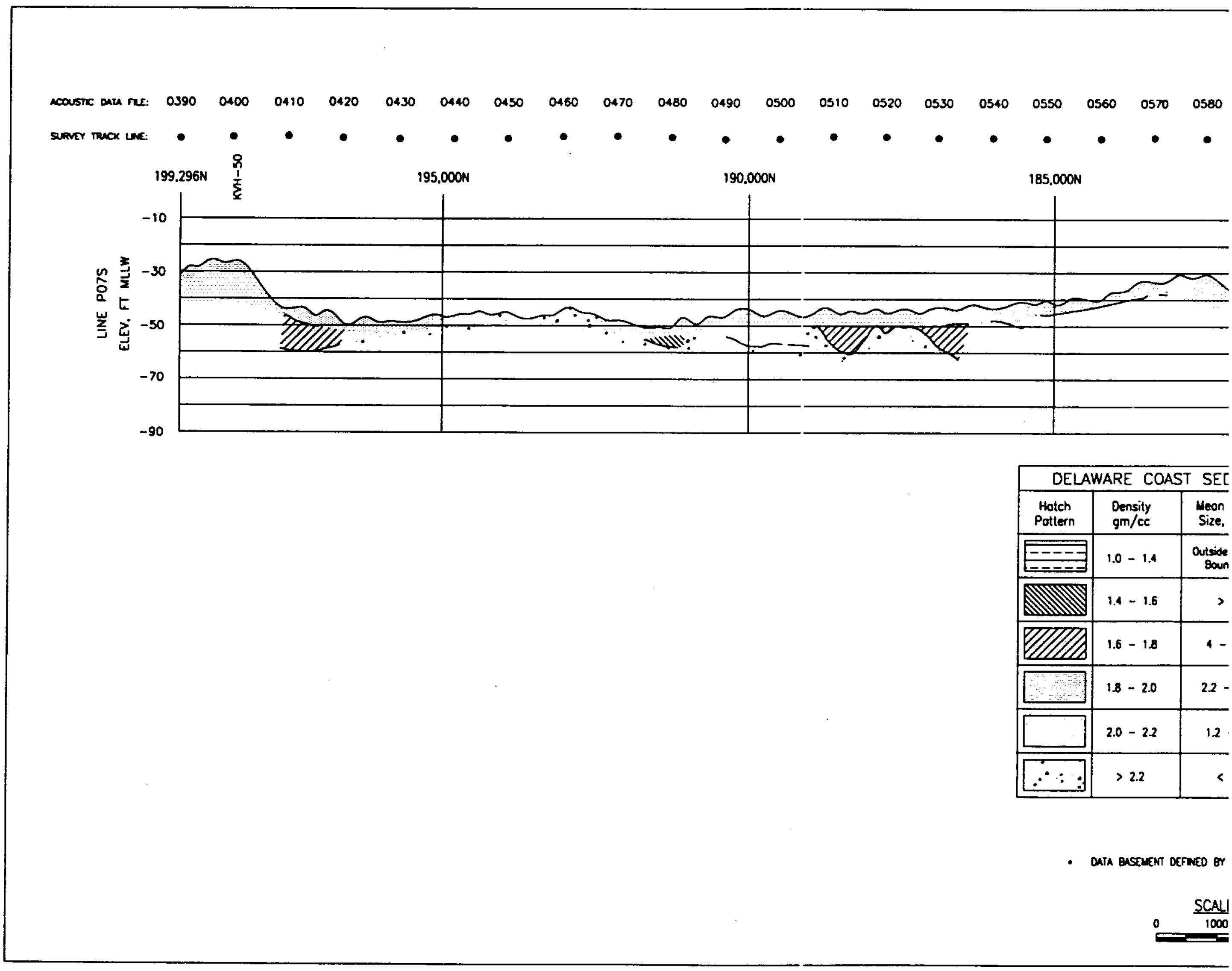
SCALE

1000 2000 FT

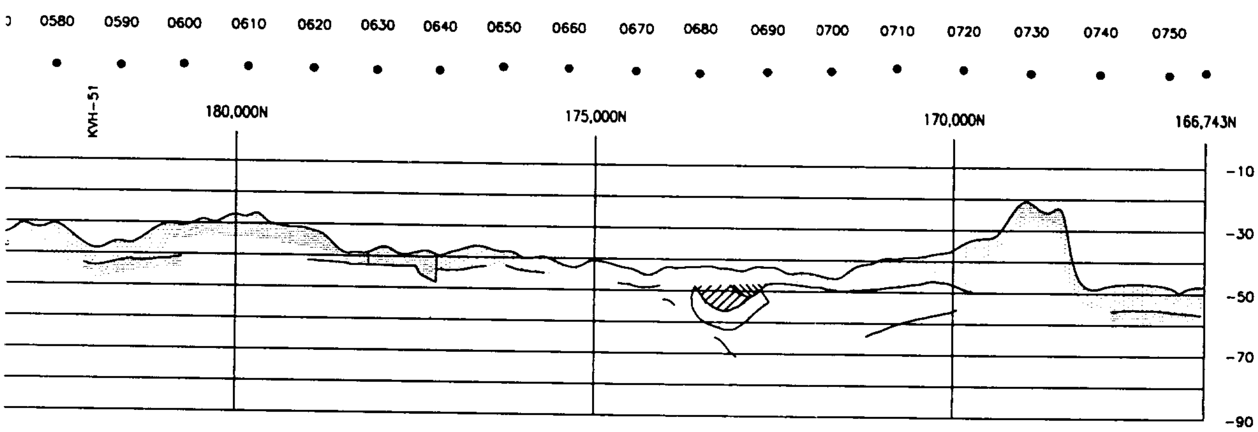
WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P06S-S

FILE NAME: P06S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 37



ACOUSTIC DATA FILE: 0390 0400 0410 0420 0430 0440 0450 0460 0470 0480 0490 0500 0510 0520 0530 0540 0550 0560 0570 0580
SURVEY TRACK LINE:
199,296N
KVH-50
195,000N
190,000N
185,000N
-10
-30
-50
-70
-90
LINE P07S
ELEV, FT MLLW
DELAWARE COAST
Hatch Pattern
Density gm/cc
Mean Size,
1.0 - 1.4
Outside
1.4 - 1.6
>
1.6 - 1.8
4 -
1.8 - 2.0
2.2 -
2.0 - 2.2
1.2
> 2.2
<
DATA BASEMENT DEFINED BY
0
1000



AST SEDIMENT DESCRIPTION

Mean Grain Size, Φ m	Basic Soil Description
Outside Model Boundary	Soft Muds, Clays
> 4	Clays, Silts, Sandy Silts
4 - 2.2	Clayey Sands, Silty Silts
2.2 - 1.2	Fine Sands
1.2 - 0	Medium Sands
< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

DEFINED BY BOTTOM OF HATCHING

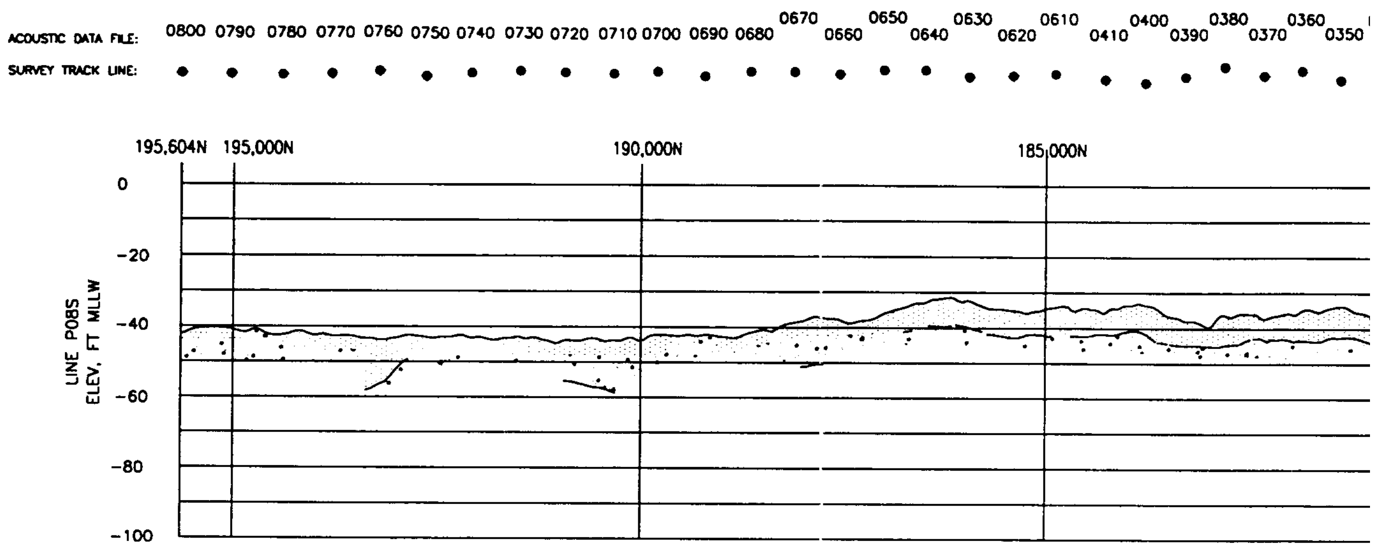
SCALE
1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P07S-S

FILE NAME: P07S-S.DWG

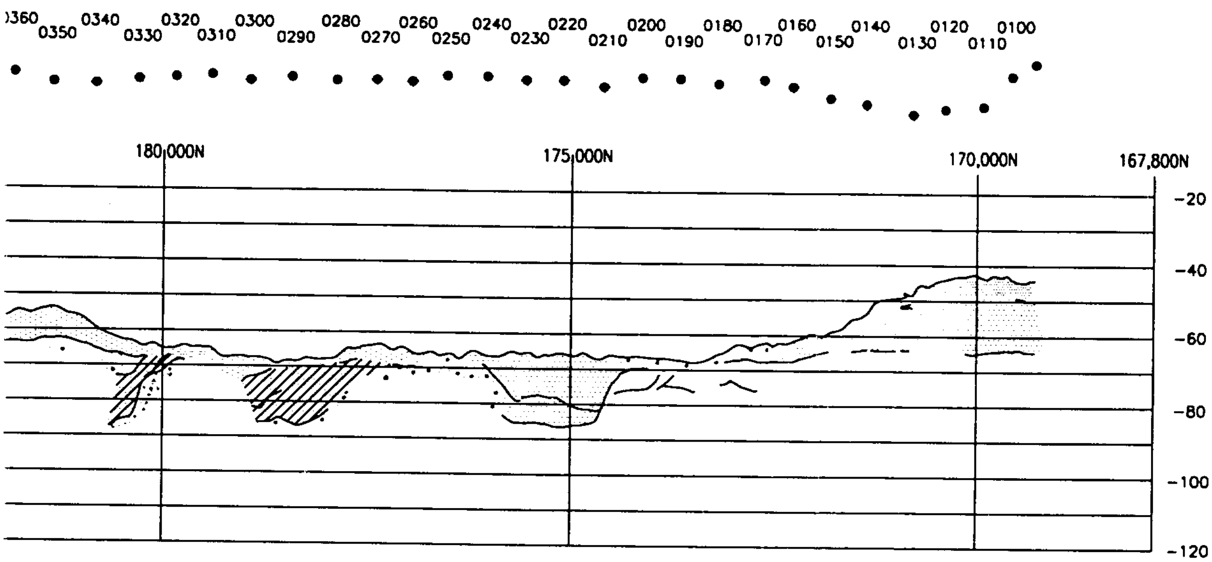
SCALE: 1"=1000' | DATE: AUGUST 9, 1995 | PLATE 33



DELAWARE COAST	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMENT DEFIN

0



COAST SEDIMENT DESCRIPTION

ty c	Mean Grain Size, Φ m	Basic Soil Description
1.4	Outside Model Boundary	Soft Muds, Clays
1.6	> 4	Clays, Silts, Sandy Silts
1.8	4 - 2.2	Clayey Sands, Silty Silts
2.0	2.2 - 1.2	Fine Sands
2.2	1.2 - 0	Medium Sands
)	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

EMENT DEFINED BY BOTTOM OF HATCHING

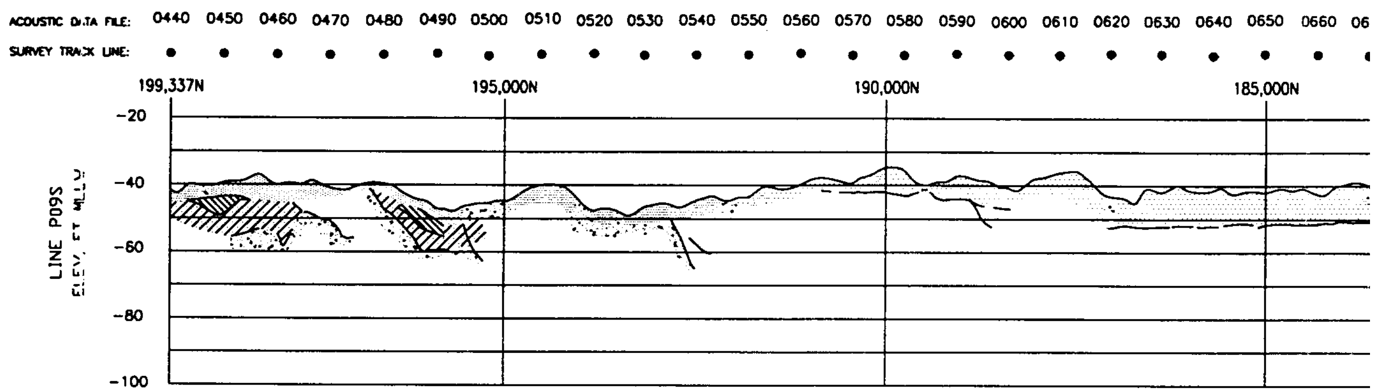
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 3918C

DELAWARE COAST
LINE P08S-S

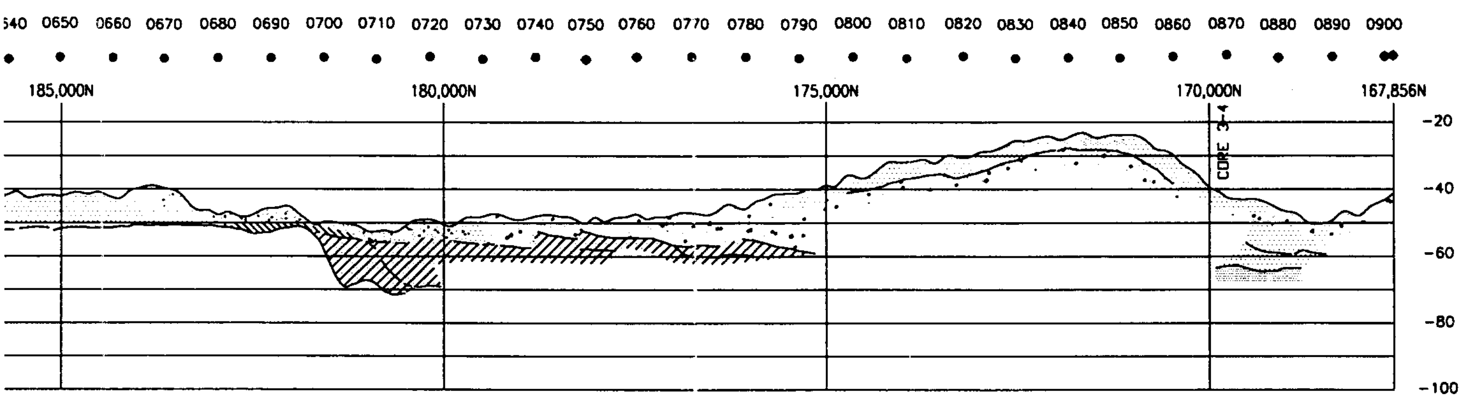
FILE NAME: P08S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLA'E 39



DELAWARE COAST	
Hatch Pattern	Density gm/cc
	1.0 - 1.4
	1.4 - 1.6
	1.6 - 1.8
	1.8 - 2.0
	2.0 - 2.2
	> 2.2

• DATA BASEMENT DEF

0



ELAWARE COAST SEDIMENT DESCRIPTION			
n	Density gm/cc	Mean Grain Size, Φ m	Basic Soil Description
	1.0 - 1.4	Outside Model Boundary	Soft Muds, Clays
	1.4 - 1.6	> 4	Clays, Silts, Sandy Silts
	1.6 - 1.8	4 - 2.2	Clayey Sands, Silty Silts
	1.8 - 2.0	2.2 - 1.2	Fine Sands
	2.0 - 2.2	1.2 - 0	Medium Sands
	> 2.2	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

- DATA BASEMENT DEFINED BY BOTTOM OF HATCHING

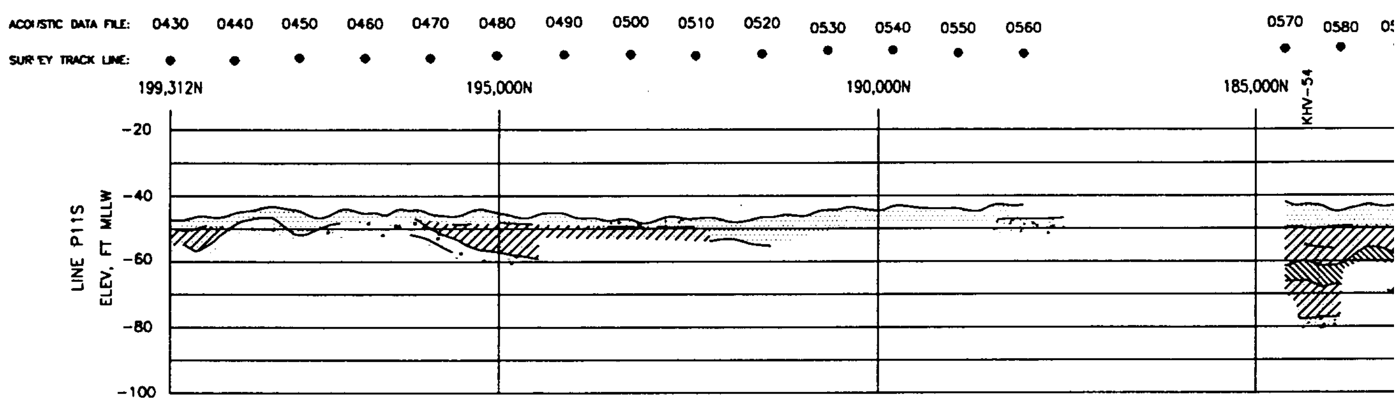
SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE COAST
LINE P09S-S

FILE NAME: P09S-S.DWG		
SCALE: 1"=1000'	DATE: AUGUST 9, 1995	PLATE 40



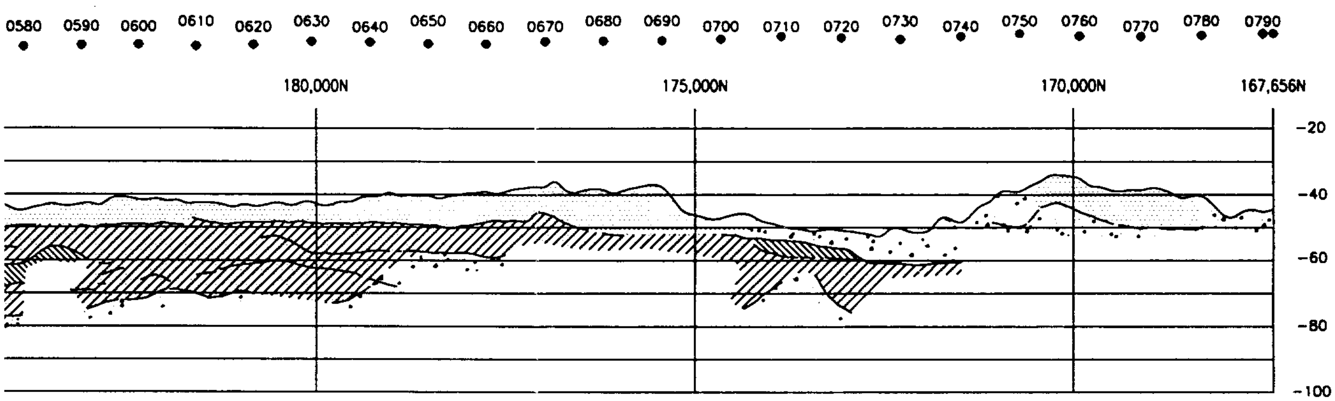
DELAWARE COAST S		
Hatch Pattern	Density gm/cc	Me Si
	1.0 - 1.4	Outs B
	1.4 - 1.6	
	1.6 - 1.8	4
	1.8 - 2.0	2.
	2.0 - 2.2	1
	> 2.2	

NO

• DATA BASEMENT DEFINED

SC

0 1



OAST SEDIMENT DESCRIPTION

	Mean Grain Size, ϕ m	Basic Soil Description
i	Outside Model Boundary	Soft Muds, Clays
5	> 4	Clays, Silts, Sandy Silts
3	4 - 2.2	Clayey Sands, Silty Silts
)	2.2 - 1.2	Fine Sands
2	1.2 - 0	Medium Sands
	< 0	Coarse Sands & Gravels, Clayey Sands w/ Gravels

NOTES

ENT DEFINED BY BOTTOM OF HATCHING

SCALE

0 1000 2000 FT

WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180		
DELAWARE COAST LINE P11S-S		
FILE NAME: P11S-S.DWG		
SCALE: 1" = 1000'	DATE: AUGUST 9, 1995	PLATE 41

Appendix A
Vibracore Sample Data

The vibracore sample data presented in this appendix include the drilling logs and laboratory gradation curves from the most recent drilling program, beginning with KHV-31 and ending with KHV-58.

Drilling Log		1 of 2 Sheets
1. Project: KHV	10. Size and Type of Bit	
2. Location: 758513.04E, 245998.51N	11. Datum for Elevation Shown (TDM or MSL): MLLW	
Drilling Agency: Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill	
4. Hole No. (As shown on drawing title): KHV-31	13. Total No. of Overburden Samples Taken	Disturbed / Undisturbed
5. Name of Driller	14. Total No. of Core Boxes	
6. Direction of Hole: [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water	
	16. Date Hole	Started 6/7/93 / Completed 6/7/93
7. Thickness of Overburden	17. Elevation Top of Hole: -27.4'	
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring: %	
9. Total Depth of Hole: 20 ft	19. Signature of Inspector: JV GZ D-JK	

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0					
		SC	Dark gray, moist, clayey sand	100		
	1					Sample at 1.0'
			Bivalve and cephalopod shells at 1'–3'			
	2					
	3	SC				Sample at 3.0'
	4			100		
	5	SC	Dark gray, moist, clayey sand			
	6					
	7					
	8					
		SC	Dark gray, moist, clayey sand	100		
	9					
	10					Sample at 10.0'

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -27.4'	Hole No. KHV-31
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11		Dark gray, clayey sand			
	12	SC				
	13					
	14		Dark gray, silty, clayey sand			
	15					Sample at 15.0'
	16					
	17	SC				
	18					
	19	SC				
	20		20 ft Recovery			
	21					

NG FORM 1836 Project Hole No.

Drilling Log | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 758513.04E, 245998.51N	11. Datum for Elevation Shown (TDM or MSL) MLLW
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-31	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/7/93 — Completed 6/7/93
7. Thickness of Overburden	17. Elevation Top of Hole -27.4'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 20 ft	19. Signature of Inspector JV GZ D-JK

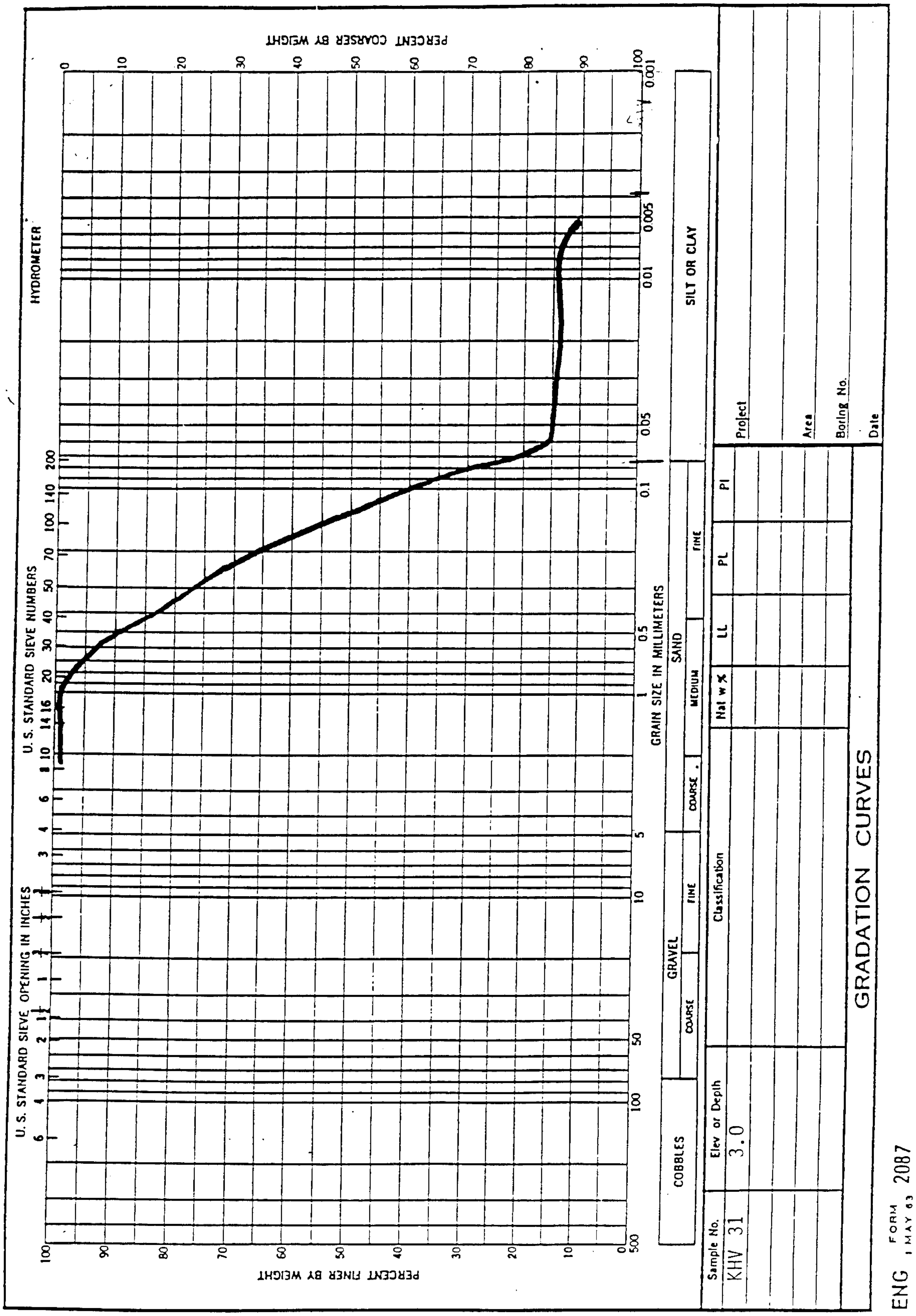
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0					
		SC	Dark gray, moist, clayey sand	100		
	1					Sample at 1.0'
			Bivalve and cephalopod shells at 1'–3'			
	2					
	3	SC				Sample at 3.0'
	4			100		
	5	SC	Dark gray, moist, clayey sand			
	6					
	7					
	8					
		SC	Dark gray, moist, clayey sand	100		
	9					
	10					Sample at 10.0'

ENG FORM 1836 | Project | Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -27.4'	Hole No. KHV-31
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11		Dark gray, clayey sand			
	12	SC				
	13					
	14		Dark gray, silty, clayey sand			
	15					Sample at 15.0'
	16					
	17	SC				
	18					
	19	SC				
	20		20 ft Recovery			
	21					

NG FORM 1836 Project Hole No.

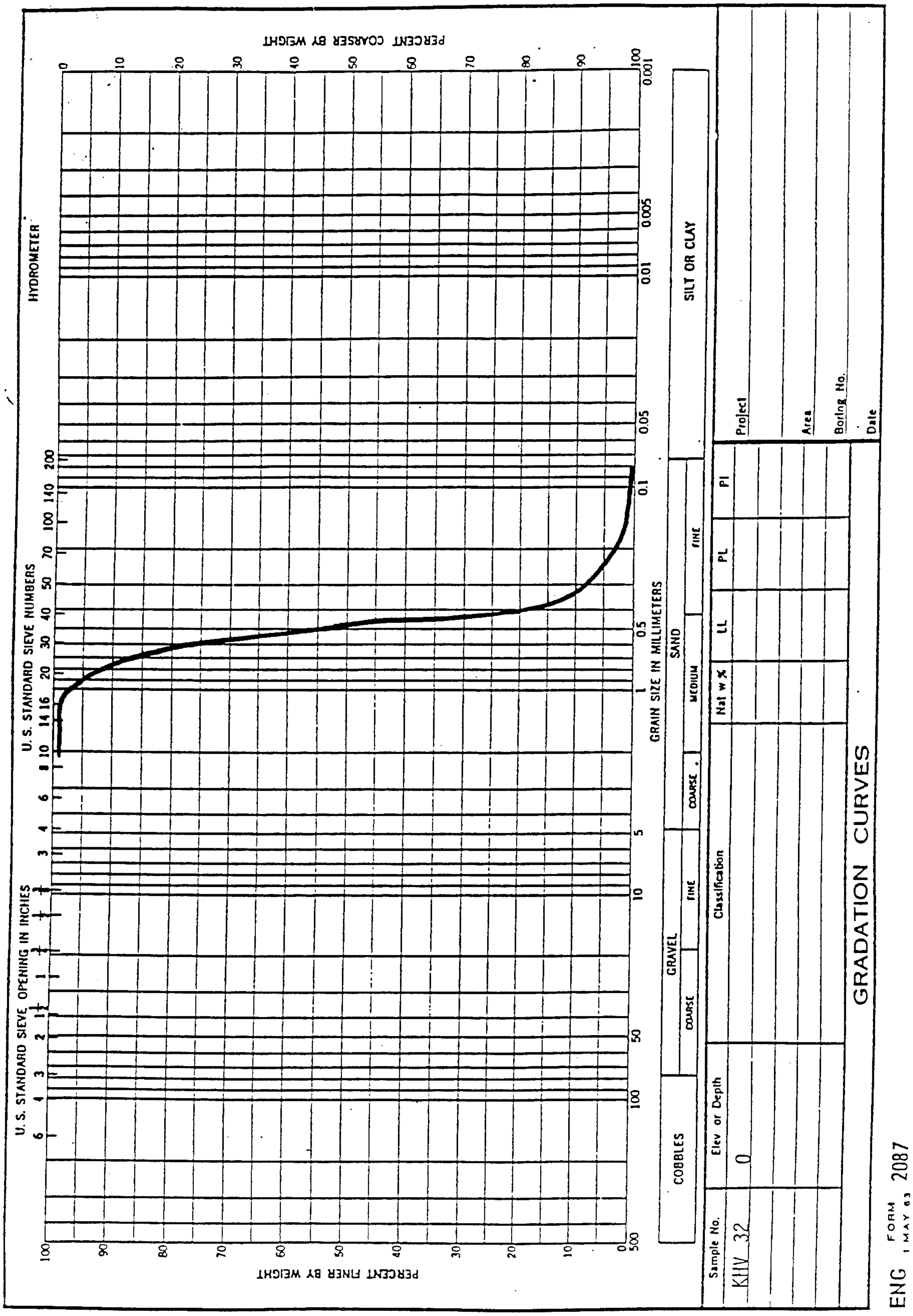

U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 31
Elev or Depth
3.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

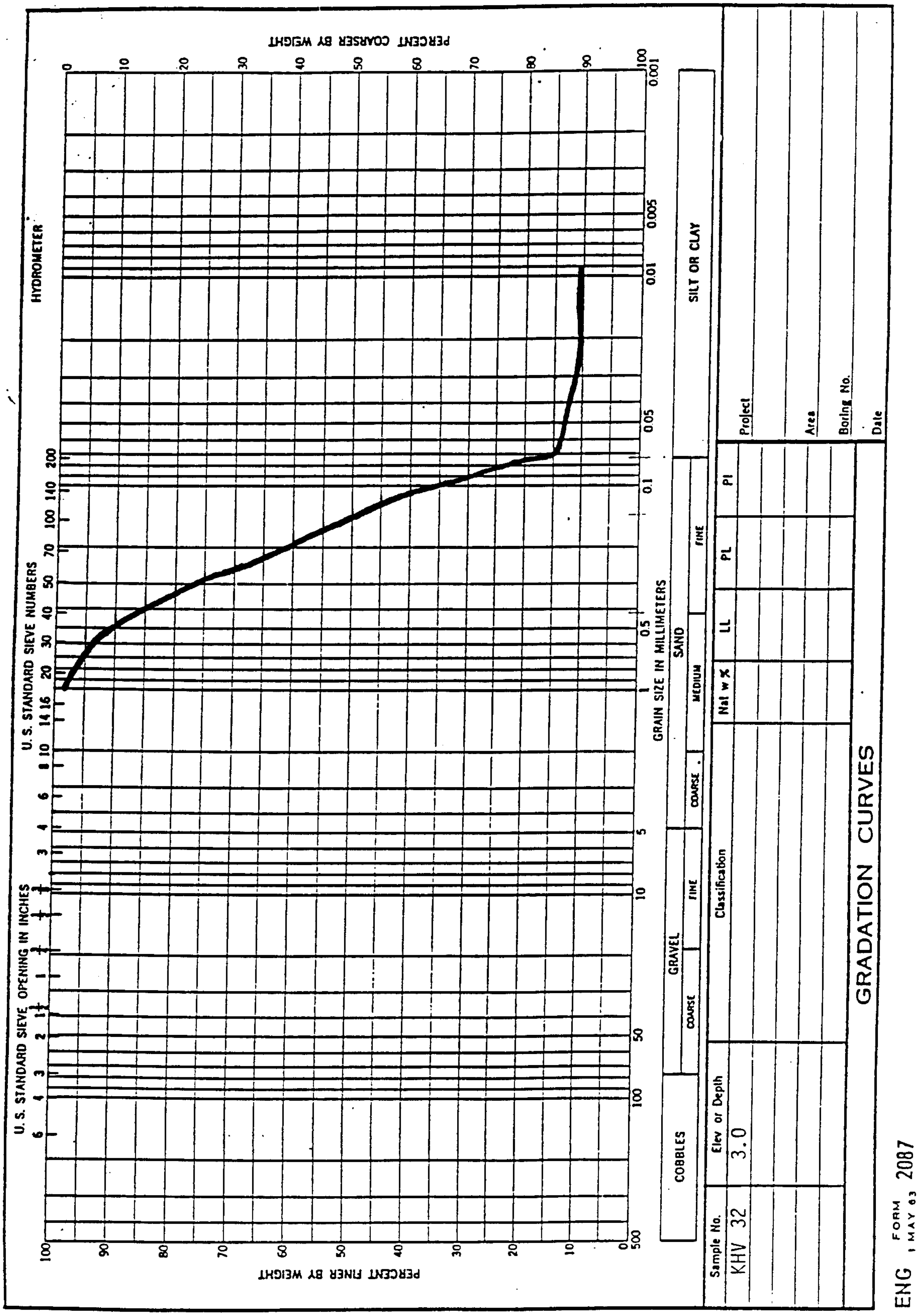
Drilling Log | 1 of 1 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 757962.03E, 259773.78N	11. Datum for Elevation Shown (TDM or MSL) MLLW
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-32	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started 6/7/93 — Completed 6/7/93
7. Thickness of Overburden	17. Elevation Top of Hole −35.8'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 8 ft	19. Signature of Inspector JV GZ

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0	SP	Medium to coarse brown sand (SW) some round gravel			Sample at 0'
	1–5	SC	Dark gray sand with some clay			Sample at 3.0' Sample at 4.0'
	5–6	SM	Dark gray, muddy sand			
	6–8	SP	Olive brown medium sand, stained with FE oxide some silt 8 ft Recovery			Sample at 7.0'
	8–10					

ENG FORM 1836 Project Hole No.


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 32
0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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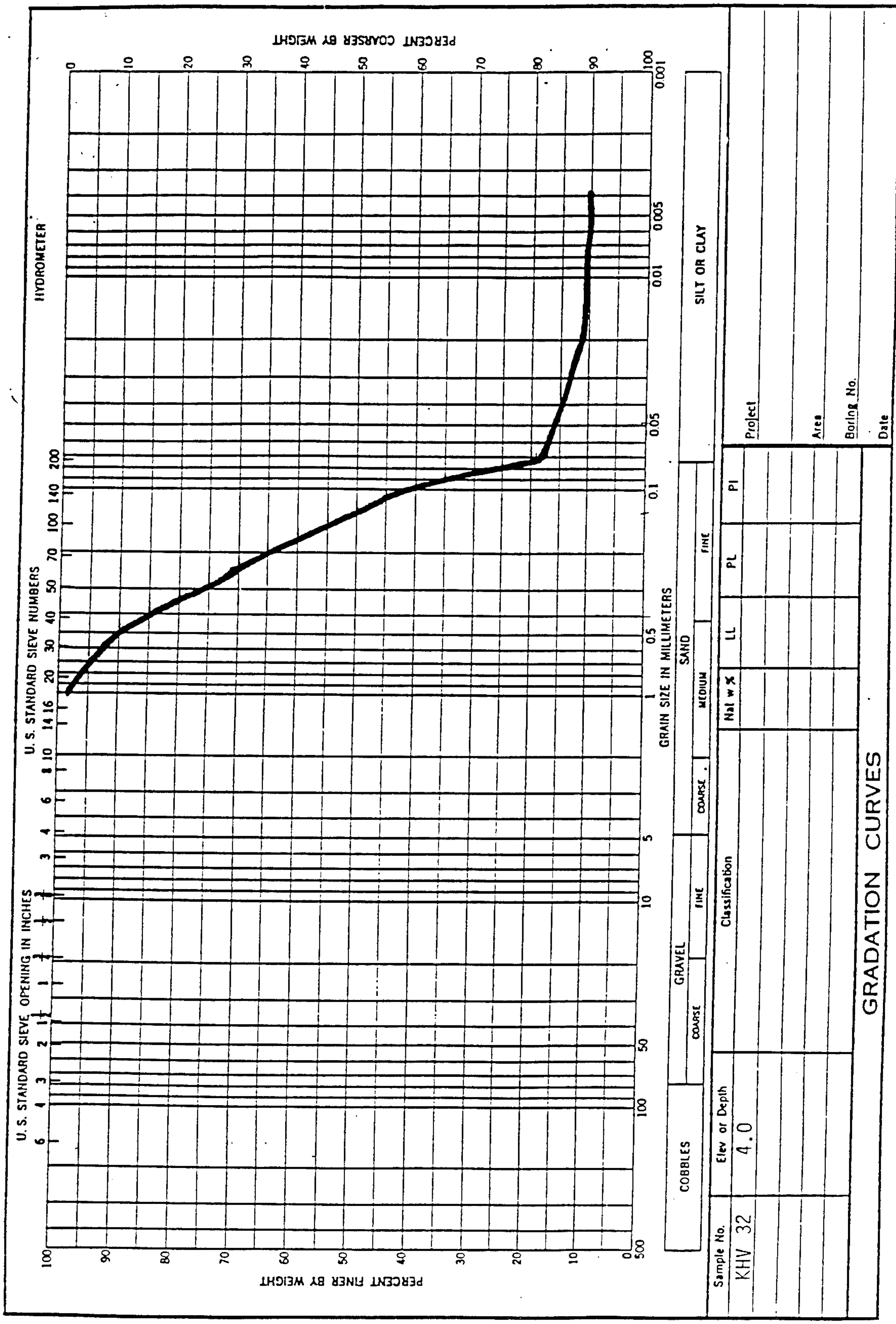
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 32
Elev or Depth
3.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
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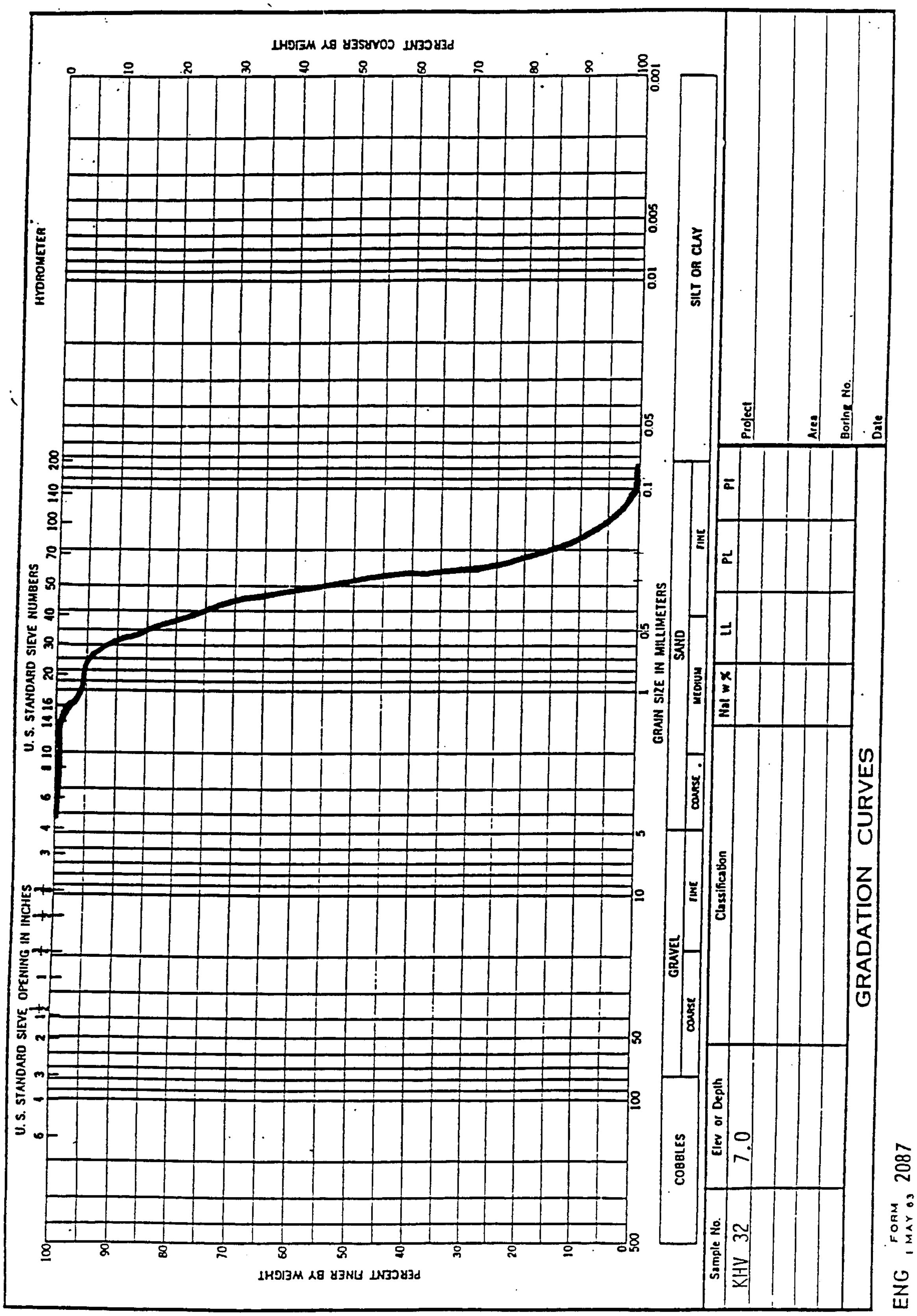
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 32
Elev or Depth
4.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 32
Elev or Depth
7.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1 of 2 Sheets

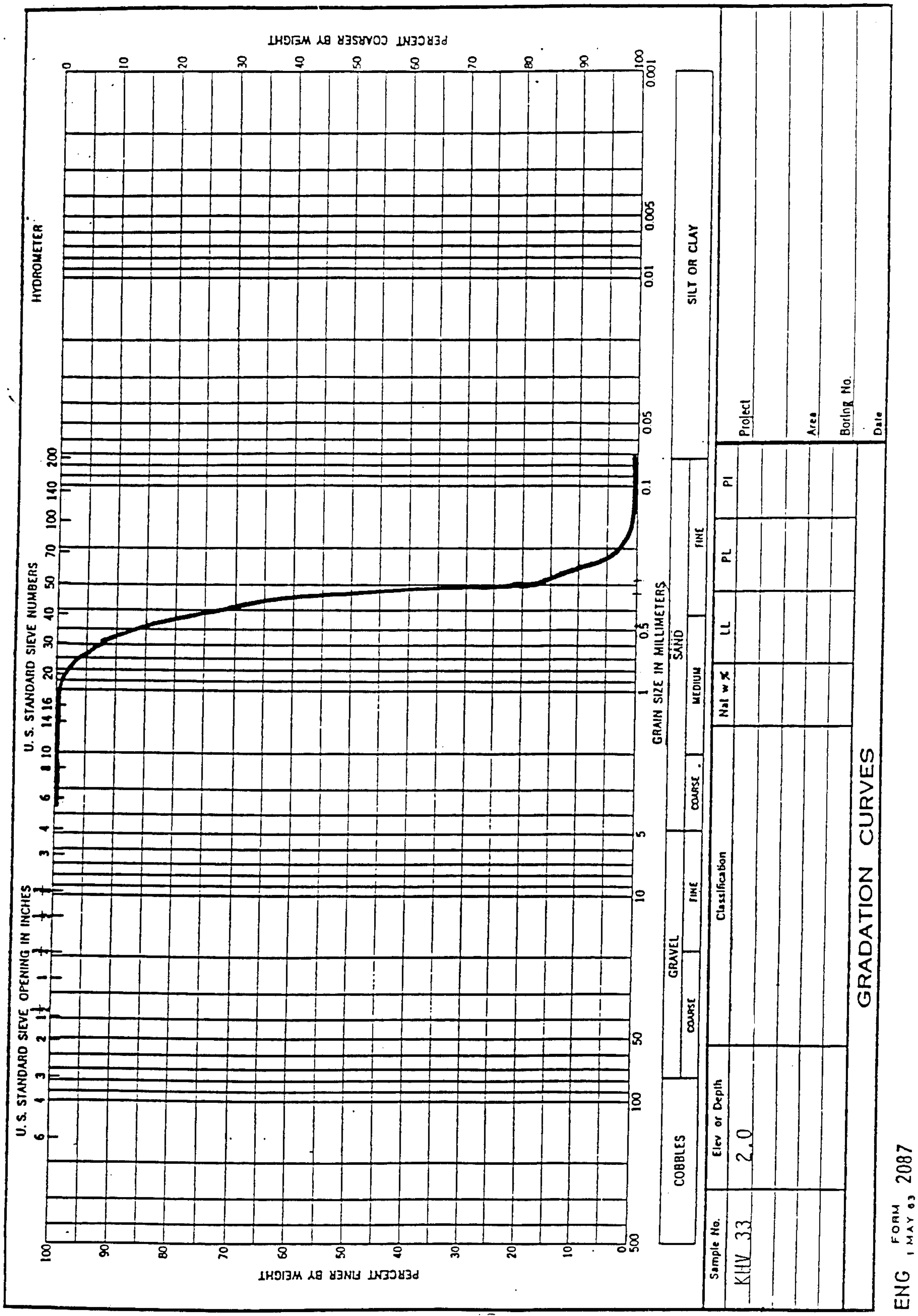
1. Project KHV	10. Size and Type of Bit
2. Location 766421.10E, 237024.90N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-33	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/9/93 — Completed 6/9/93
7. Thickness of Overburden	17. Elevation Top of Hole -31.6'
8. Depth Drilled into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 18.6 ft	19. Signature of Inspector JV GZ

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0	SP				
	1					
			Gray to tan, medium sand—dry			
	2					Sample at 2.0'
	3					
	4	SP	Gray to tan, medium sand			
	5					
	6					Sample at 6.0'
	7					
	8		Gray to tan, medium sand			
	9	SP				
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -31.6'		Hole No. KHV-33			
Project KHV		Installation			Sheet 2 of 2 Sheets	
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray to tan, medium sand			
	11					Sample at 11'
	12					
	13					
	14	SP	Gray to tan, medium sand			
	15					
	16					Sample at 16.0'
	17					
	18		18.6 ft Recovery			
	19					
	20					
	21					

NG FORM 1836 Project Hole No.



GRADATION CURVES
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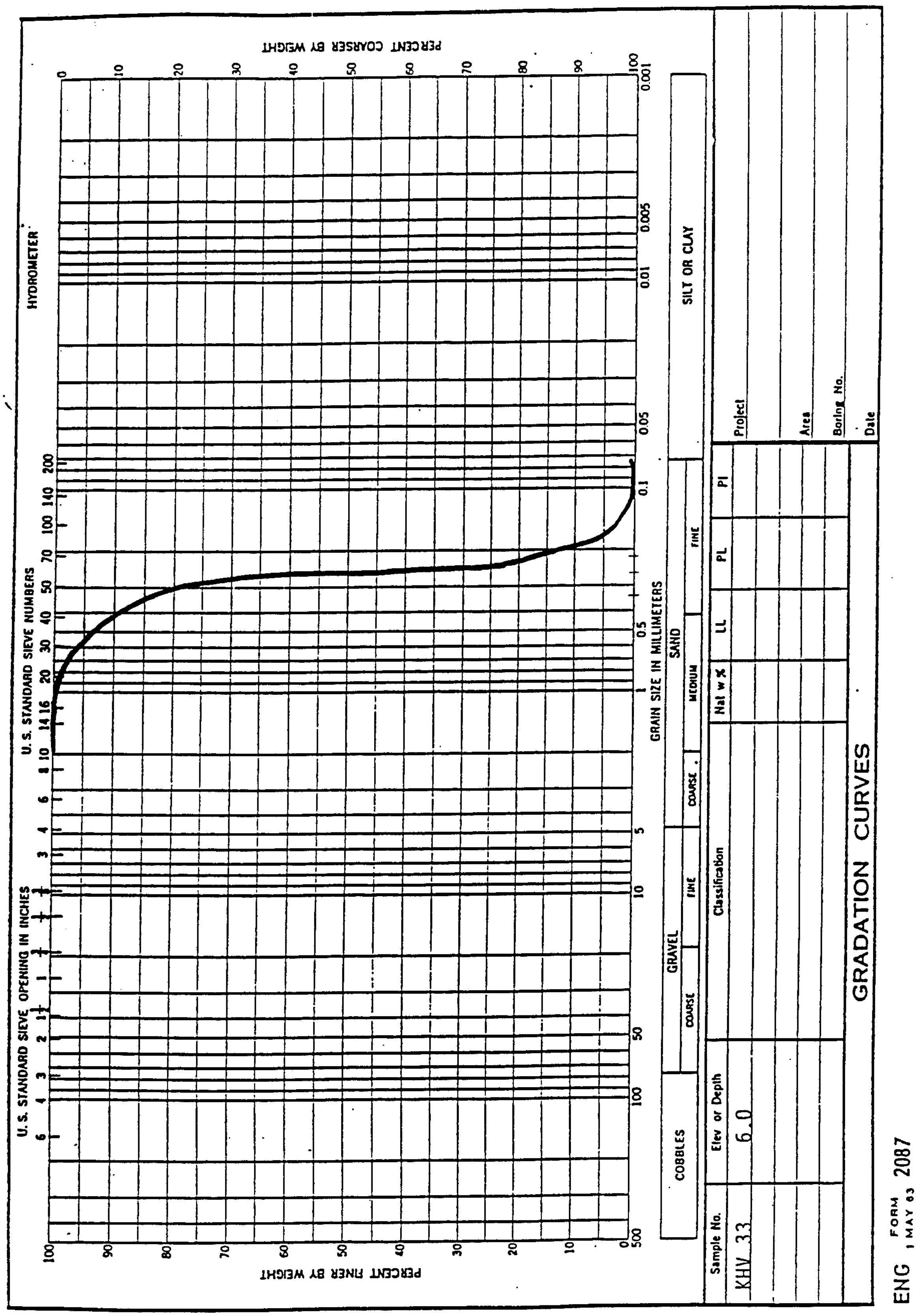
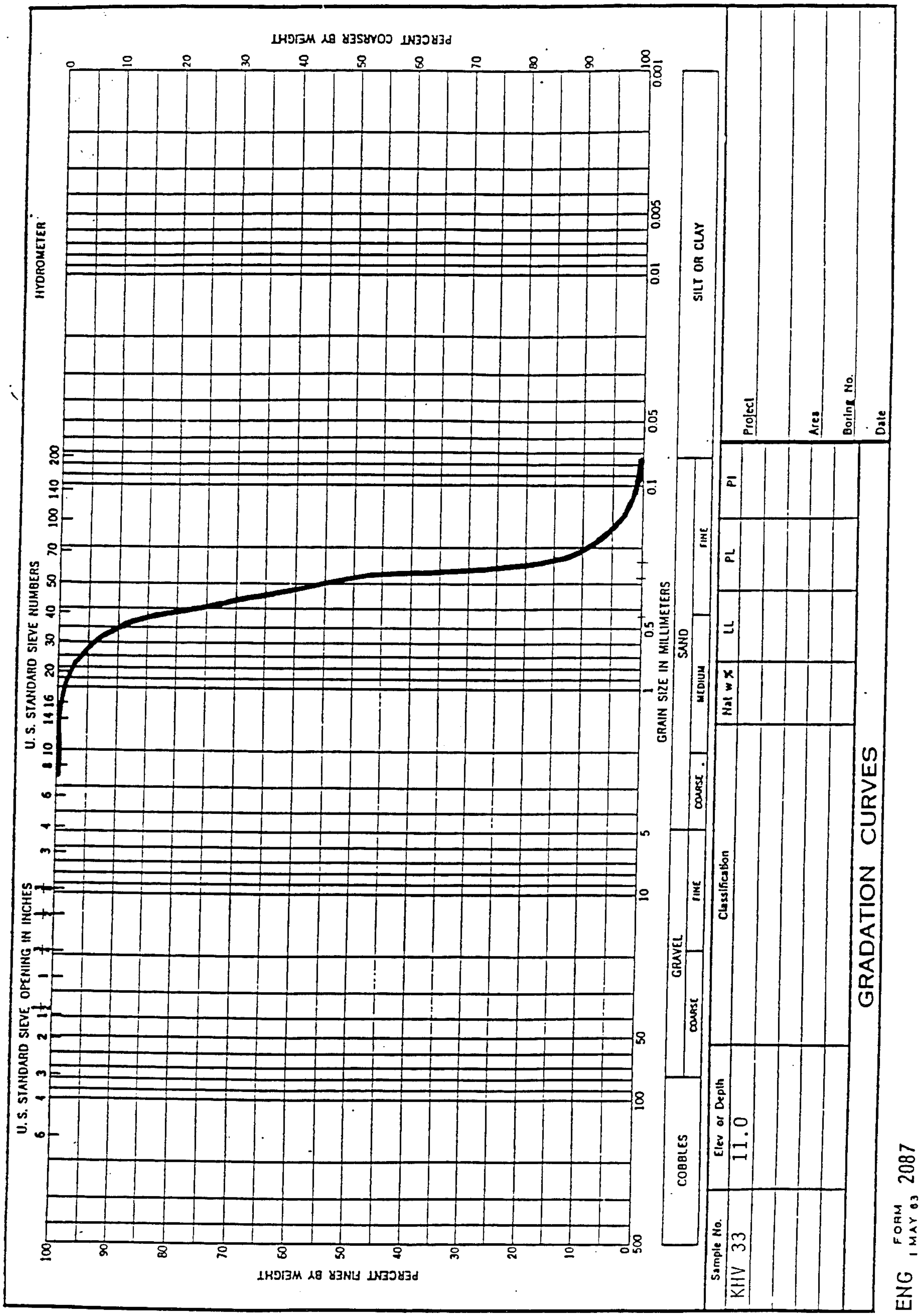
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 33
2.0
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 33
6.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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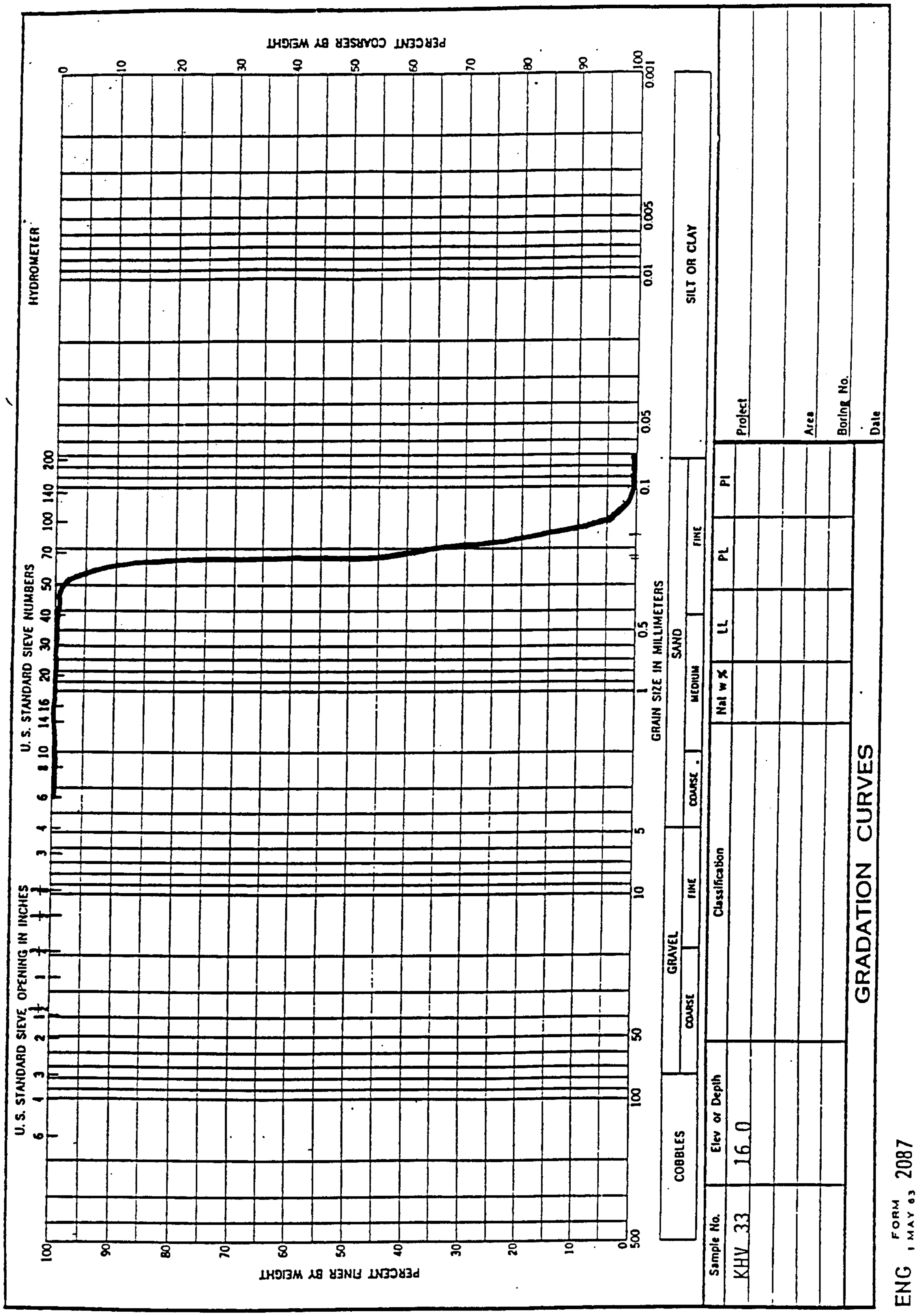
HYDROMETER
U. S. STANDARD SIEVE NUMBERS
U. S. STANDARD SIEVE OPENING IN INCHES
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 33
Elev or Depth
11.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 33
16.0
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	1 of 2 Sheets
2. Location 762849.96E, 250044.53N	10. Size and Type of Bit
Drilling Agency Alpine Ocean Seismic Survey, Inc.	11. Datum for Elevation Shown (TBM or MSL) MLLW
4. Hole No. (As shown on drawing title) KHV-34	12. Manufacturer's Designation of Drill
5. Name of Driller	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	14. Total No. of Core Boxes
7. Thickness of Overburden	15. Elevation Ground Water
8. Depth Drilled Into Rock	16. Date Hole — Started 6/7/93 — Completed 6/7/93
9. Total Depth of Hole 20 ft	17. Elevation Top of Hole -41.7'
	18. Total Core Recovery for Boring %
	19. Signature of Inspector JV GZ

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–2.5	CH	Dark gray clay; moist, rigid, high plasticity	100		
	2.5–4.2	SP	Dark gray medium sand; rounded quartz sand; trace rounded gravel	100		Sample at 3.0'
	4.2–7.8	CH	Dark gray clay; rigid, plastic, stained in places with FE Oxide			H_2S smell 5'–10' core
	7.8–10	CH	Dark gray clay			

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -41.7'	Hole No. KHV-34
Project KHV	Installation	Sheet 2 of 2 Sheets

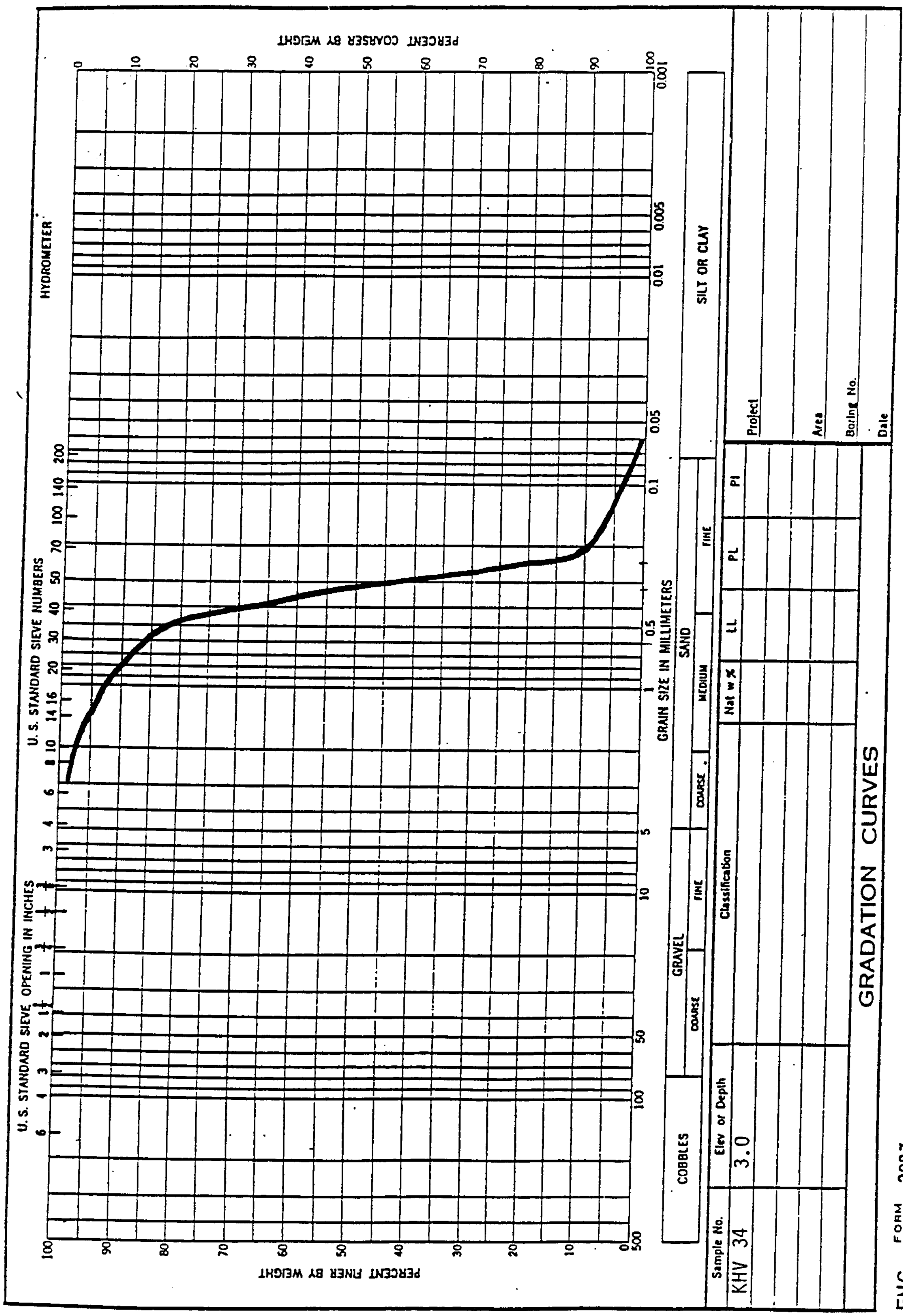
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if signficant) g
	10		Dark gray, rigid plastic clay as above Occasional gastropod shell			H_2S smell
	11					
	12		Dark gray clay			
	13	CH				
	14					
	15					
	16	CH				
	17					
	18	CH	Dark gray clay			
	19					
	20		20 ft Recovery			
	21					

NG FORM 1836 Project Hole No.

1. Project KHV	10. Size and Type of Bit
2. Location 761484.85E, 269070.42N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-35	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/8/93 — Completed 6/8/93
7. Thickness of Overburden	17. Elevation Top of Hole -24.3'
8. Depth Drilled into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 20 ft	19. Signature of Inspector JV MC

Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0–3	SP	Brown, fine sand	100		Sample at 1.4'
	3–6	SP	Brown, medium sand with traces of shell			
	6–10	SP	Fine to medium brown sand with traces of a dark mineral	100		Sample at 8.0'

ENG FORM 1836 | Project | Hole No.

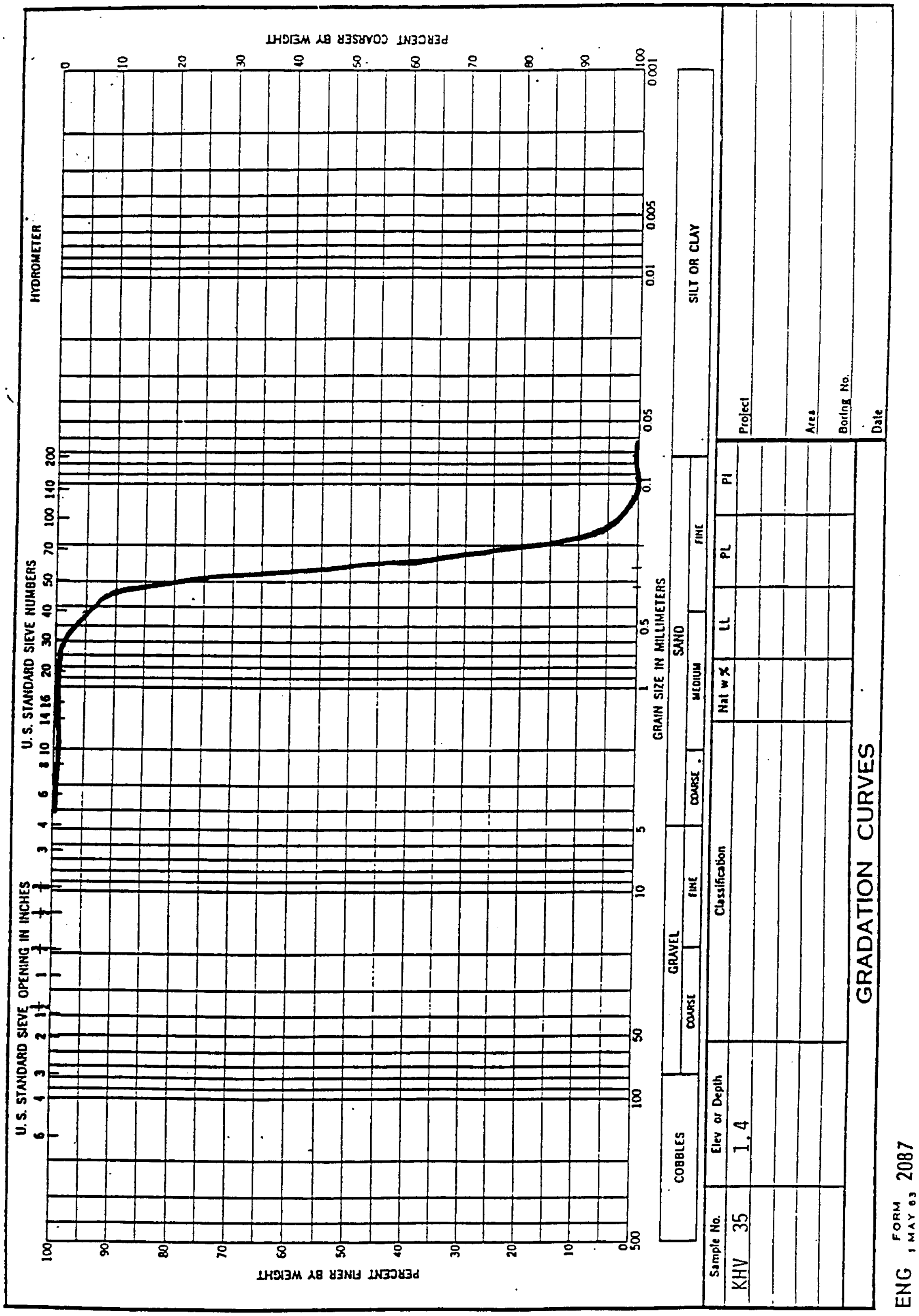


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 34
Elev or Depth
3.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log (Cont Sheet)	Elevation Top of Hole -24.3'	Hole No. KHV-35
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Brown, fine to medium sand	100		
	11					
	12		Occasional lens of gray clay			
			Occasional shells	100		
	13					Sample at 13.3'
	14	SP				
	15		Brown, fine to medium sand			
	16					
	17	SP				Sample at 16.8'
				100		
	18					
	19		Brown, fine sand			
			20 ft Recovery			
	20					
	21					

IG FORM 1836 Project Hole No.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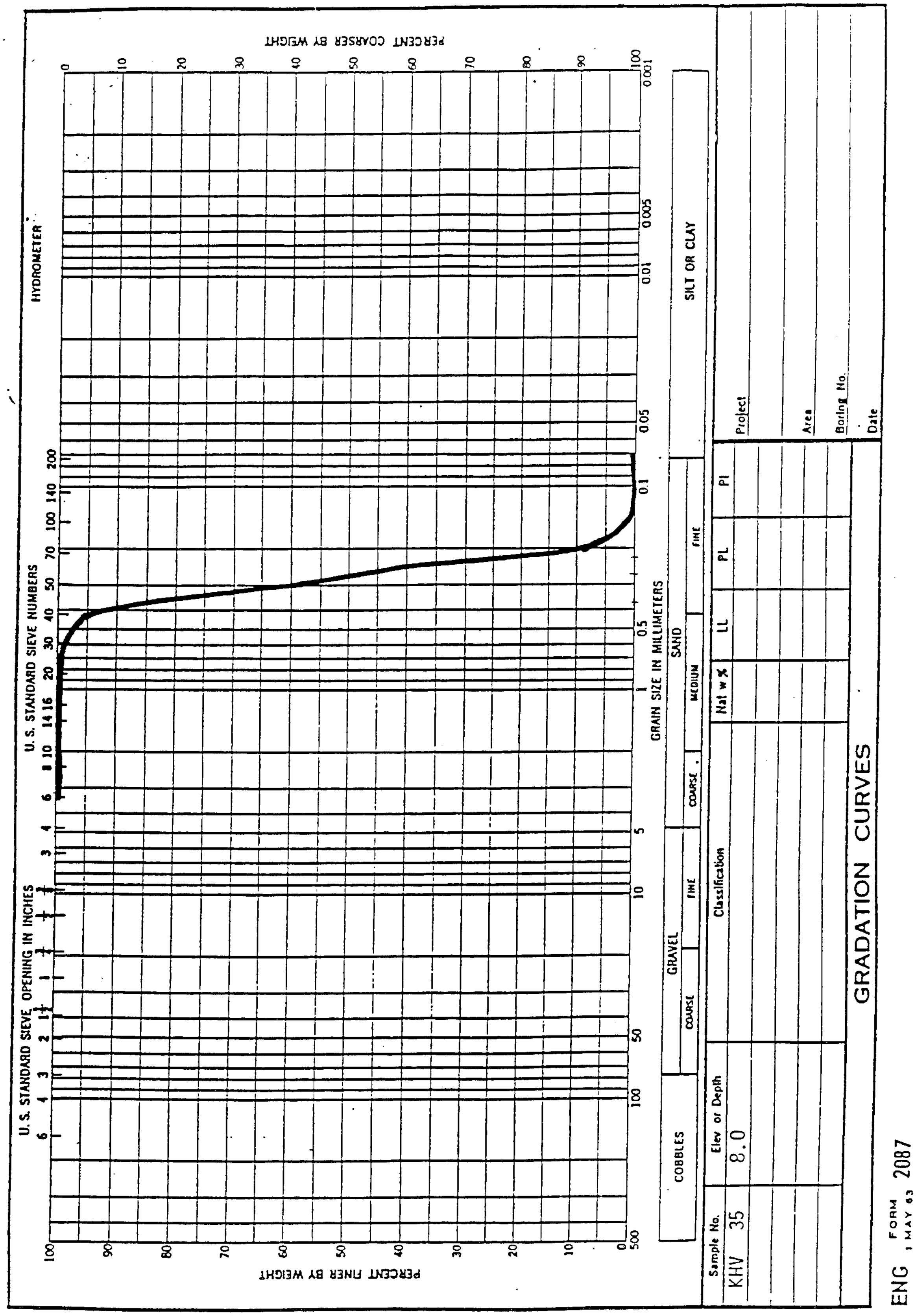
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 35
Elev or Depth
1.4
Classification
Nat w%
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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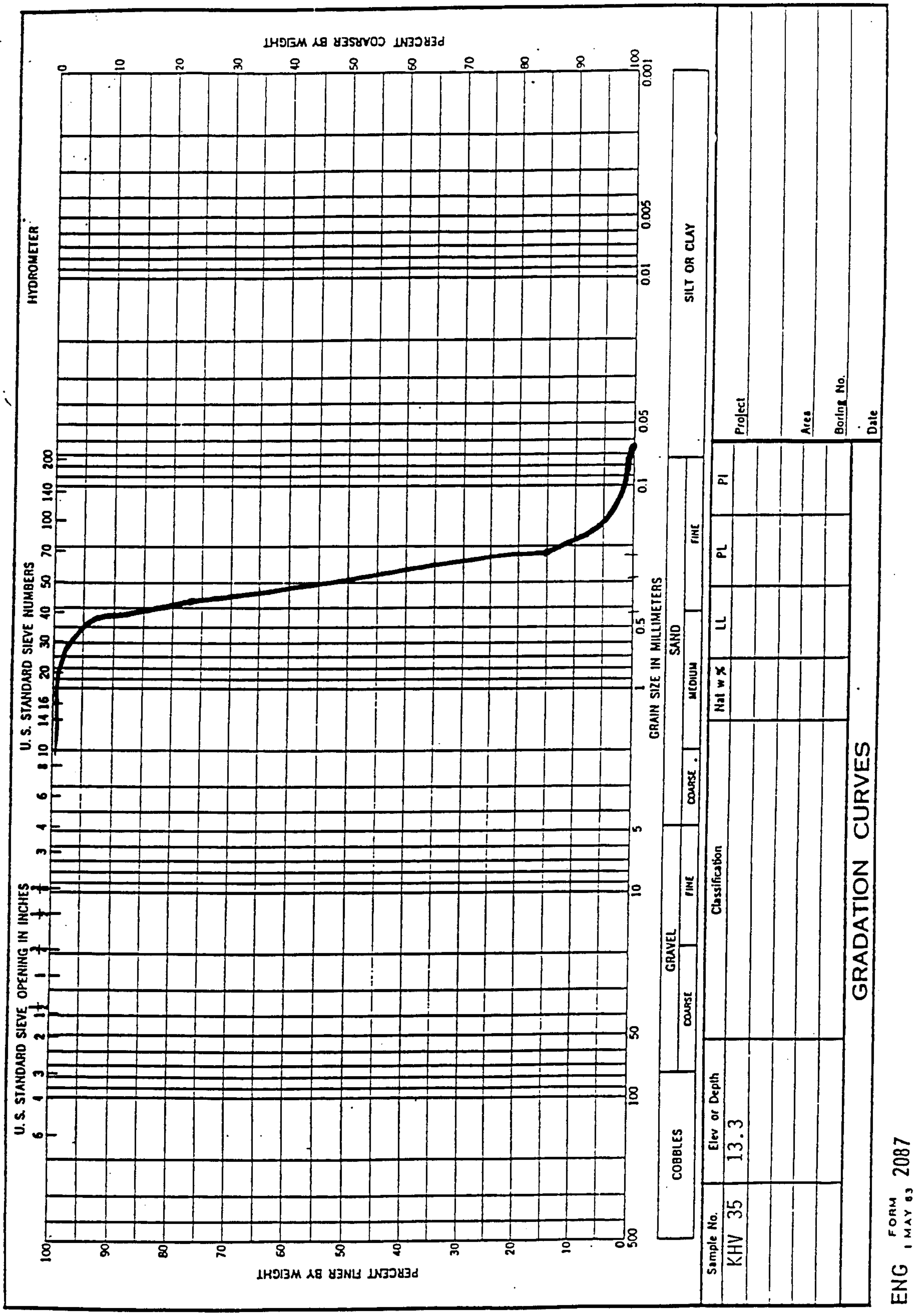
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 35
Elev or Depth
8.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 35
Elev or Depth
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Nat w %
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Area
Boring No.
Date
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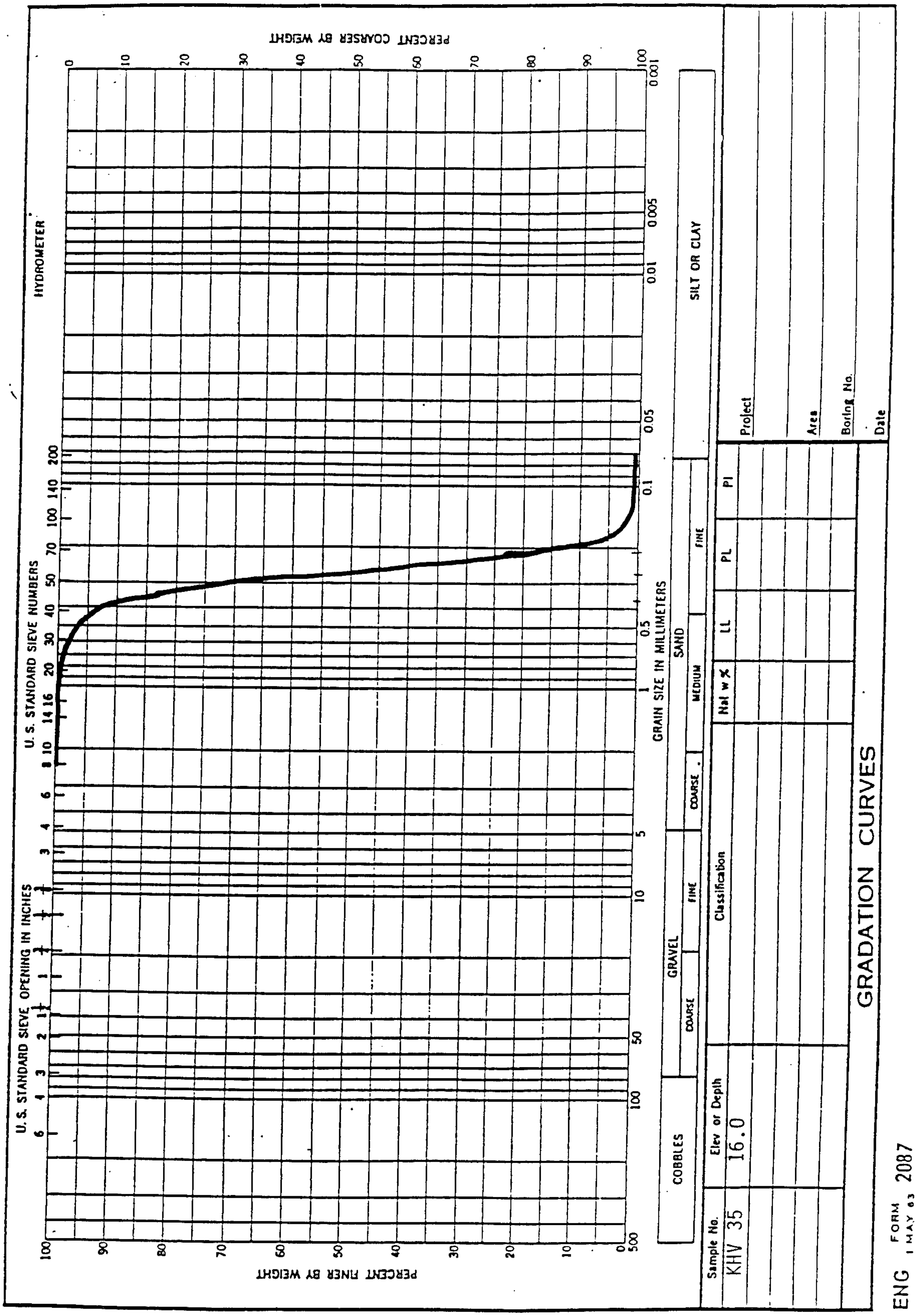
ENG FORM 1 MAY 63 2087



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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 35
Elev or Depth
16.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log	
1. Project KHV	10. Size and Type of Bit
2. Location 767206.80E, 232926.30N	11. Datum for Elevation Shown (TDM or MSL) MLLW
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-36	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/10/93 — Completed 6/10/93
7. Thickness of Overburden	17. Elevation Top of Hole -40.4'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 13 ft	19. Signature of Inspector JV GZ

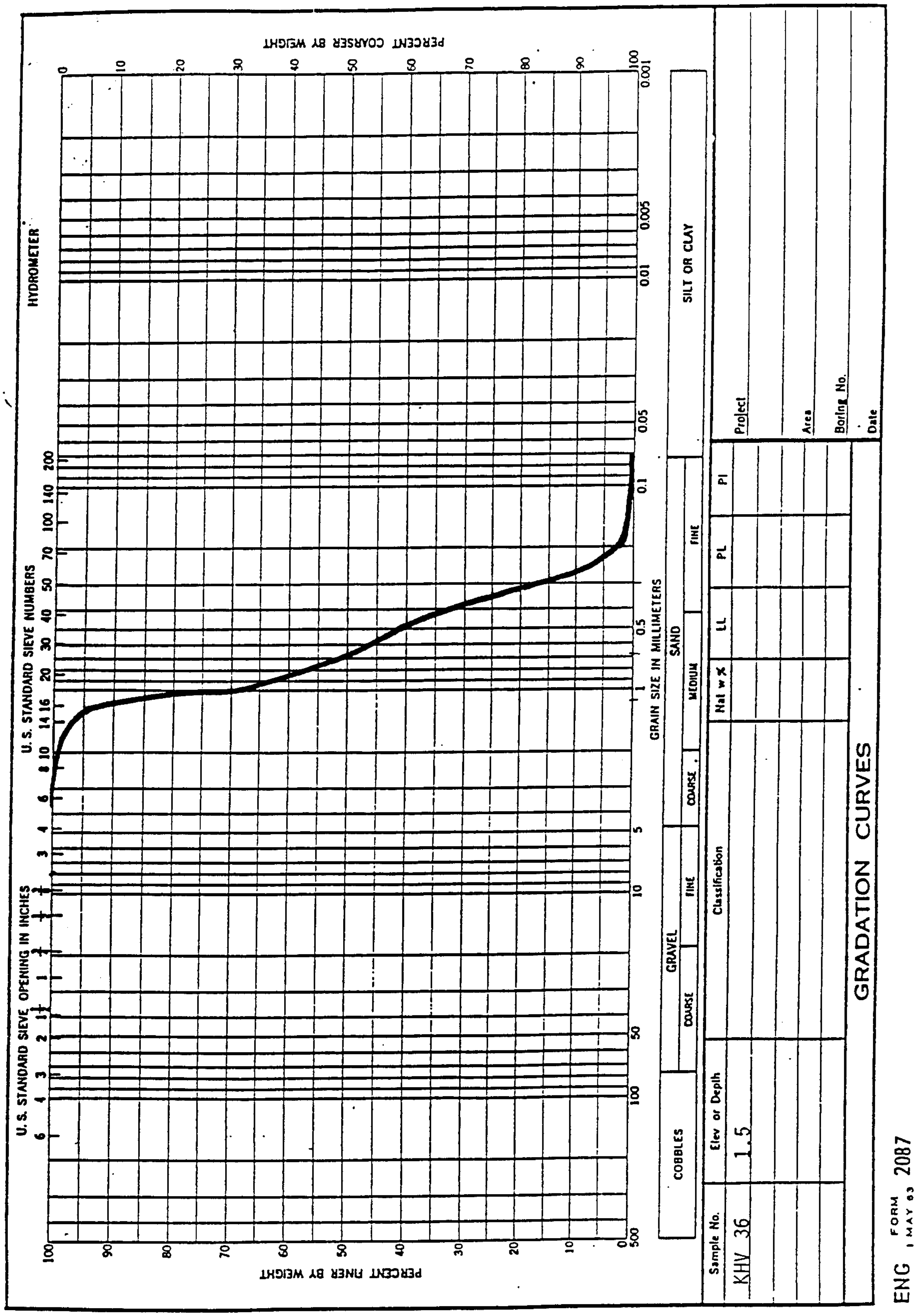
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–2	SP	Gray, medium sand with lenses of clay	100		Sample at 1.5'
	2–4	SM	Gray, silty, clayey sand	100		
	4–10	CH	Gray clay, high plasticity; occasional large shell	100		Sample at 4.5'

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -40.4'	Hole No. KHV-36
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	CH				
	11		Gray plastic clay	100		
	12					
	13		13 ft Recovery			
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					

IG FORM 1836 Project Hole No.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U.S. STANDARD SIEVE NUMBERS
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PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 36
Elev or Depth
1.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 764487.67E, 260360.78N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-37	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started 6/8/93 — Completed 6/8/93
7. Thickness of Overburden	17. Elevation Top of Hole -42.2'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 18 ft	19. Signature of Inspector JV GZ

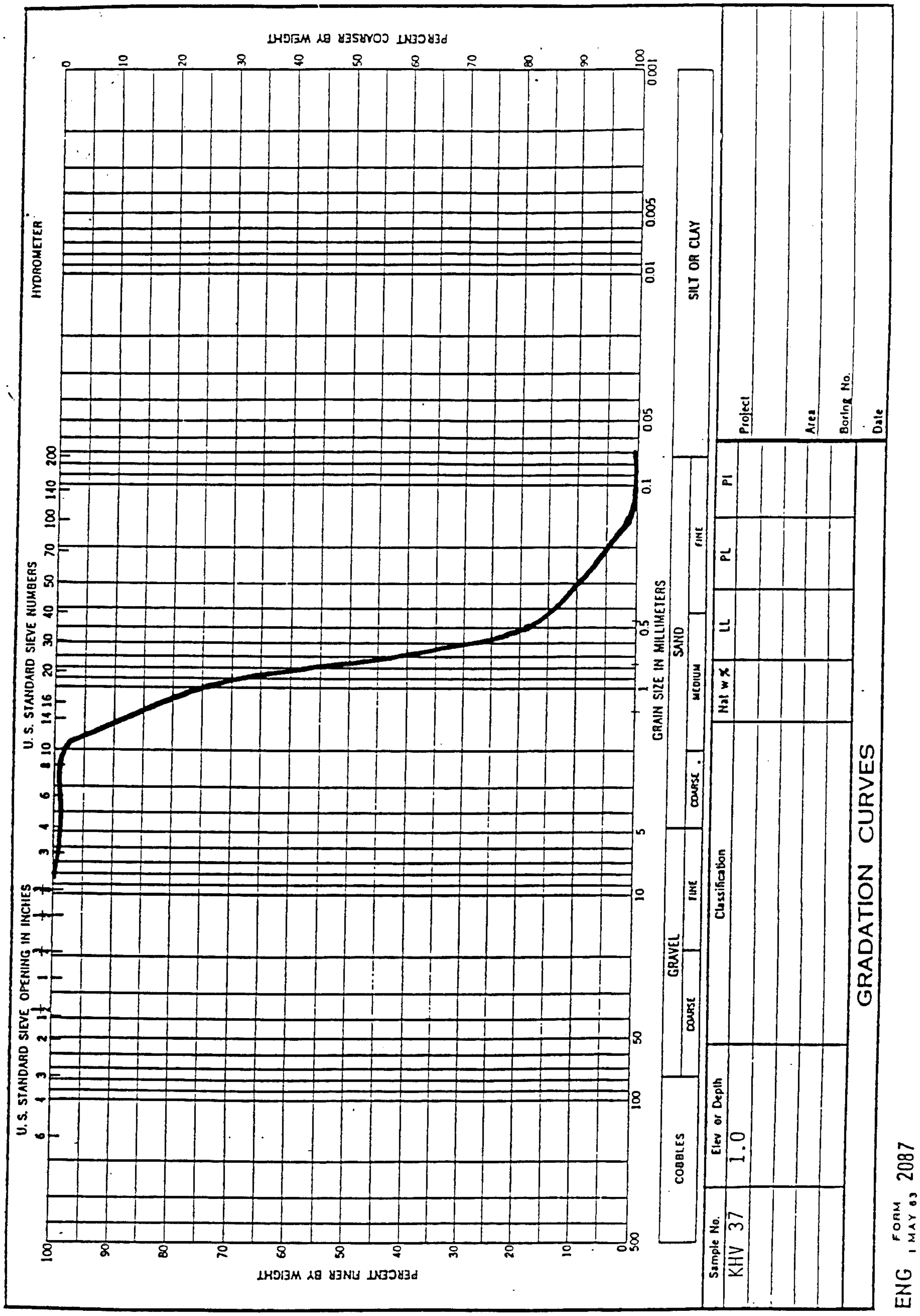
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0					
		SP	(Gravel) Dark gray, medium sand; some shells; some Fe oxide zones Course, very rounded gravel at 0'–1'.	100		Sample at 1.0'
	1					
	2		Stringers of clay			
	3	SP	Dark gray, Fe-oxide-stained, silty medium sand	100		Sample at 3.5'
	4		Green, rigid clay			
	5	SP	Coarse, well-rounded quartz sand Fe Oxide abundant Lens of very coarse round gravel at 5.5' Fine round gravel at 6' and again at 7'	100		
	6					
	7					Sample at 7.0'
	8	SP	Light brown, coarse sand, trace rounded fine gravel			
	9		Light brown, medium clean sand			
	10					Large cobble (6" long), very rounded at 10'

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -42.2'	Hole No. KHV-37
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Light brown, medium sand			
	11		Orange, coarse sand; some well-rounded gravel			Sample at 11.0'
	12	SP				
	13			100		
	14					
	15	SP				Sample at 15.0'
	16		Yellow to orange coarse sand			
	17	SP				
	18		18 ft Recovery			
	19					
	20					
	21					

NG FORM 1836 Project Hole No.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U.S. STANDARD SIEVE NUMBERS
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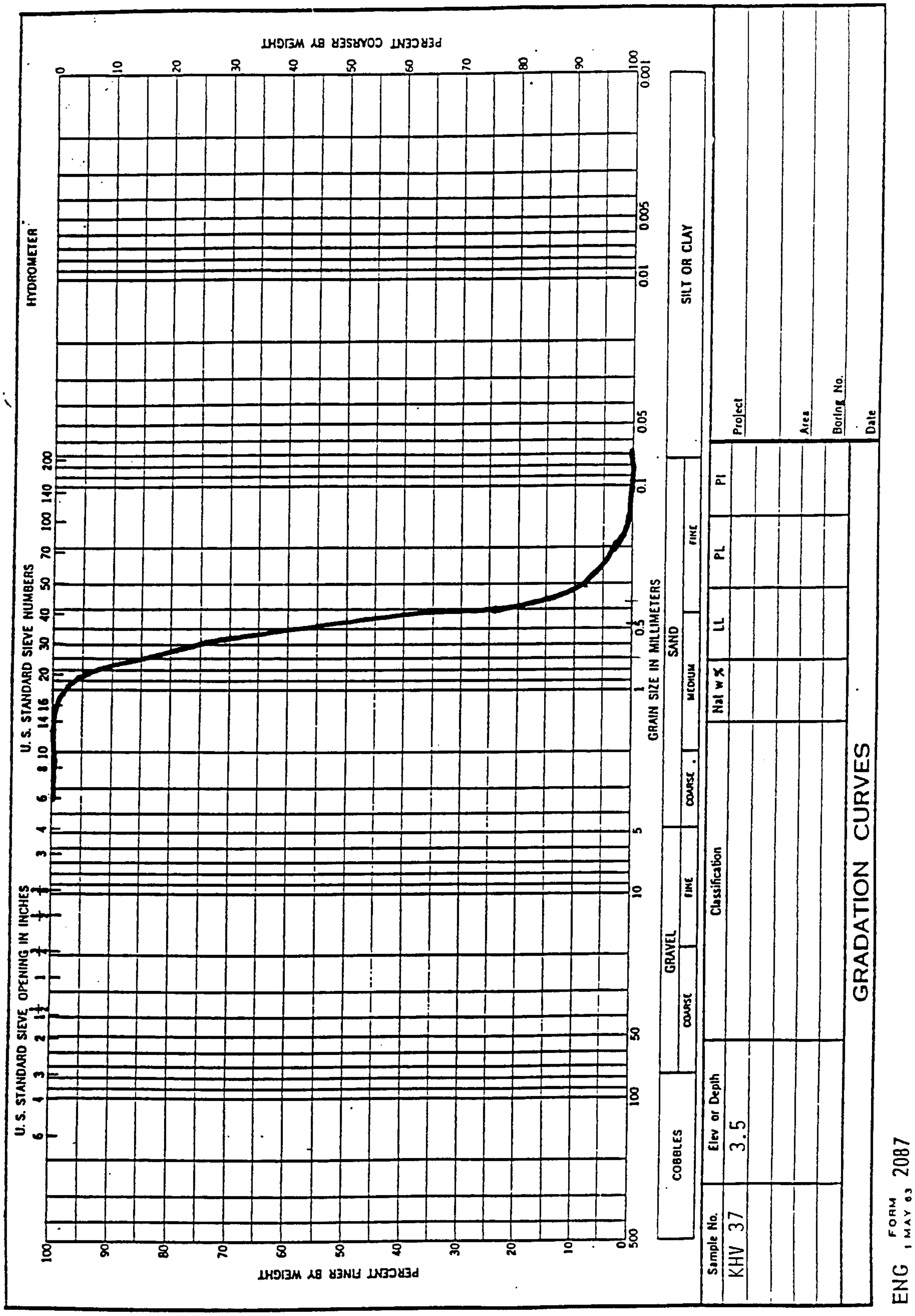
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
MEDIUM
SILT OR CLAY
Sample No.
KHV 37
Elev or Depth
1.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
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PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 37
Elev or Depth
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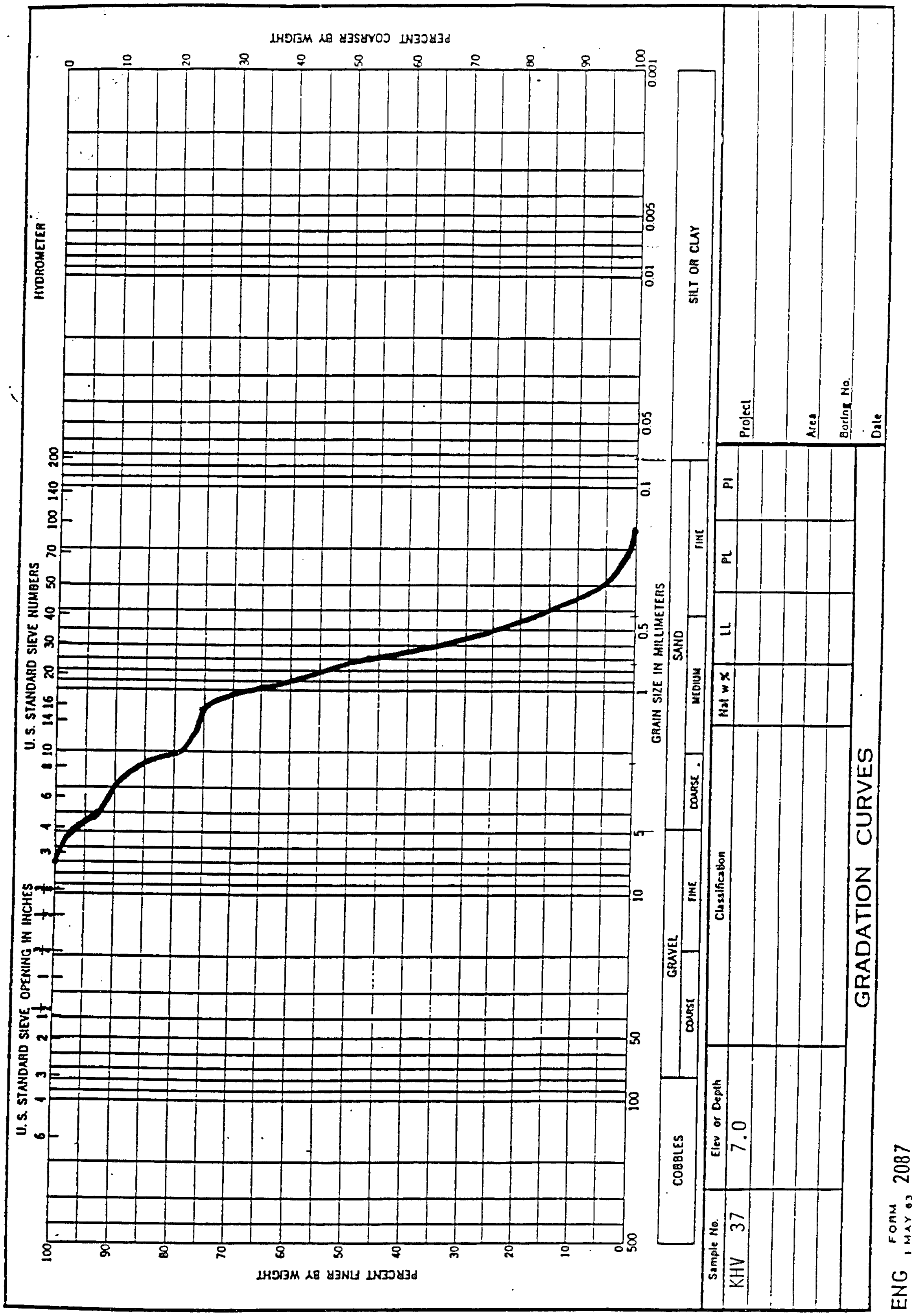
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U.S. STANDARD SIEVE OPENING IN INCHES
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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
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SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 37
Elev or Depth
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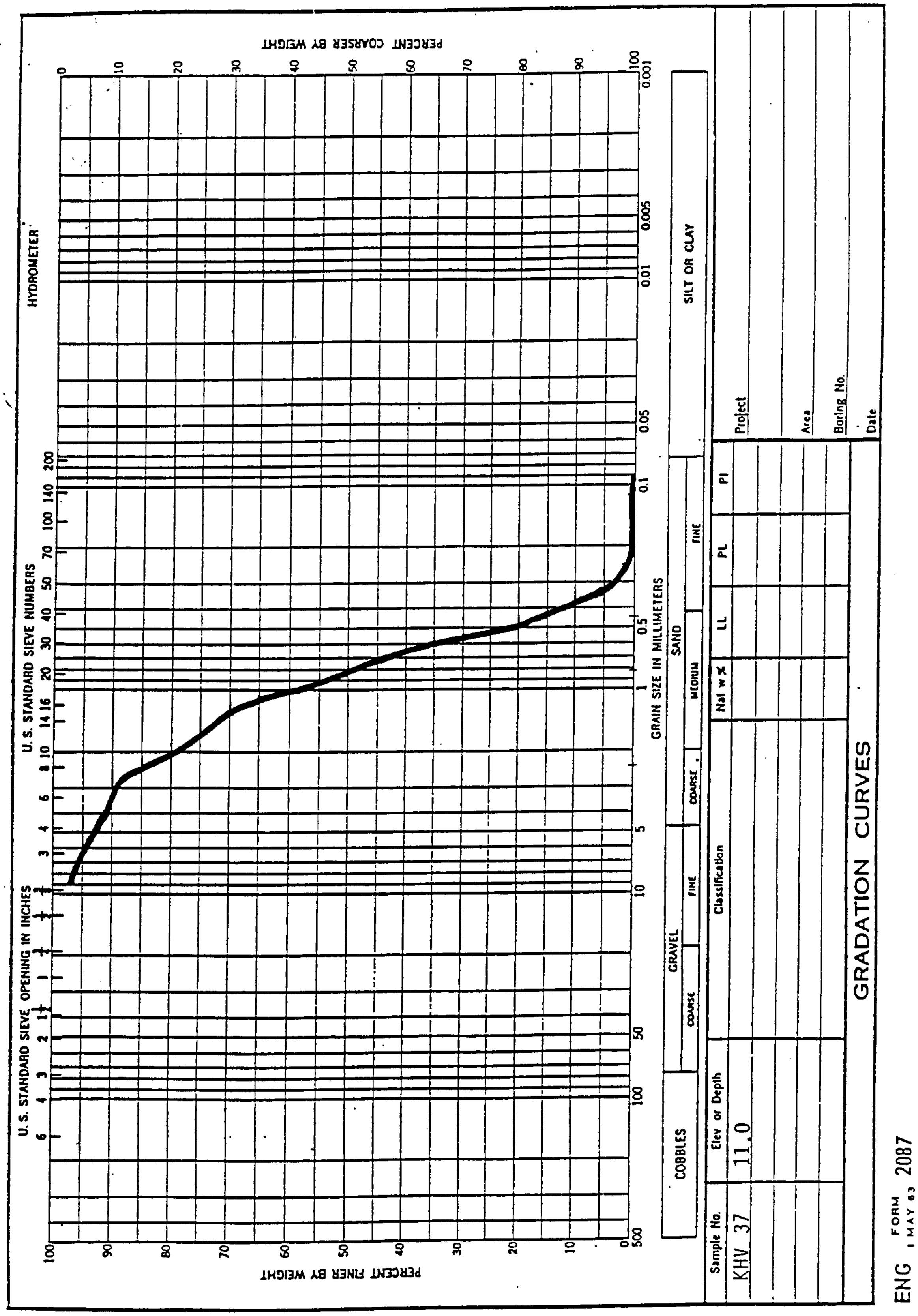
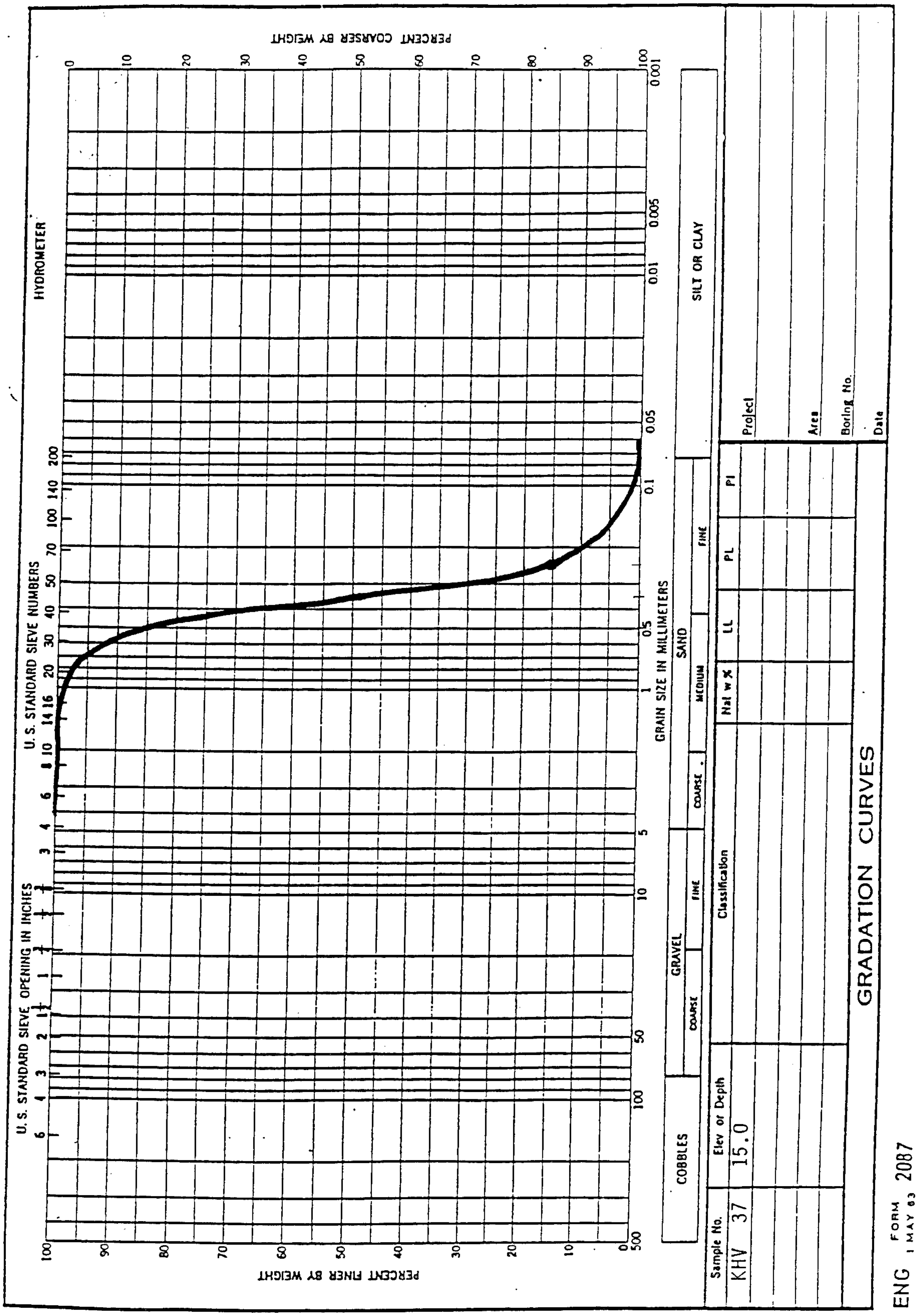
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 37
Elev or Depth
11.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087


GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 37
Elev or Depth
15.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log

1 of 2 Sheets

1. Project: KHV

2. Location: 771243.60E, 23[illegible]8958.70N

Drilling Agency: Alpine Ocean Seismic Survey, Inc.

4. Hole No. (As shown on drawing title): KHV-38

5. Name of Driller:

6. Direction of Hole: [x] Vertical [ ] Inclined ________ Degree from Vertical

7. Thickness of Overburden

8. Depth Drilled Into Rock

9. Total Depth of Hole: 17.4 ft

10. Size and Type of Bit

11. Datum for Elevation Shown (TDM or MSL): MLLW

12. Manufacturer's Designation of Drill

13. Total No. of Overburden Samples Taken: Disturbed | Undisturbed

14. Total No. of Core Boxes

15. Elevation Ground Water

16. Date Hole: Started 6/9/93 | Completed 6/9/93

17. Elevation Top of Hole: -48.6'

18. Total Core Recovery for Boring: %

19. Signature of Inspector: JV GZ

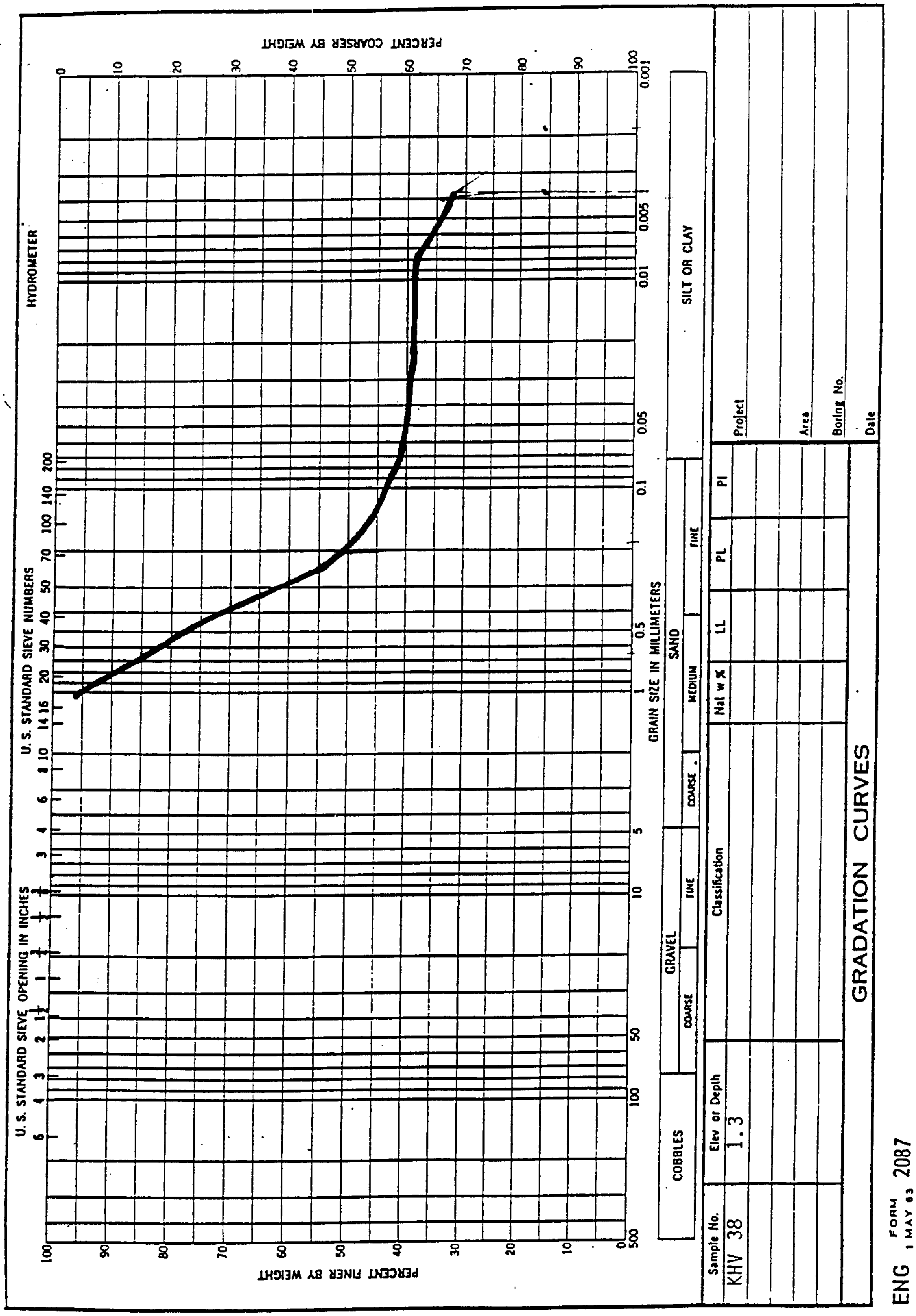
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0	SC	Dark gray-brown clayey sand; occasional shell	100		
	1					Sample at 1.3'
	2					
	3	SC	Dark gray-brown, clayey sand			
	4					
	5					Sample at 5.4'
	6	SC	Dark gray-brown, clayey sand			
	7			100		
	8	SM	Muddy sand with traces of peat			
	9					Sample at 9.2'
	10					

ENG FORM 1836 Project Hole No.

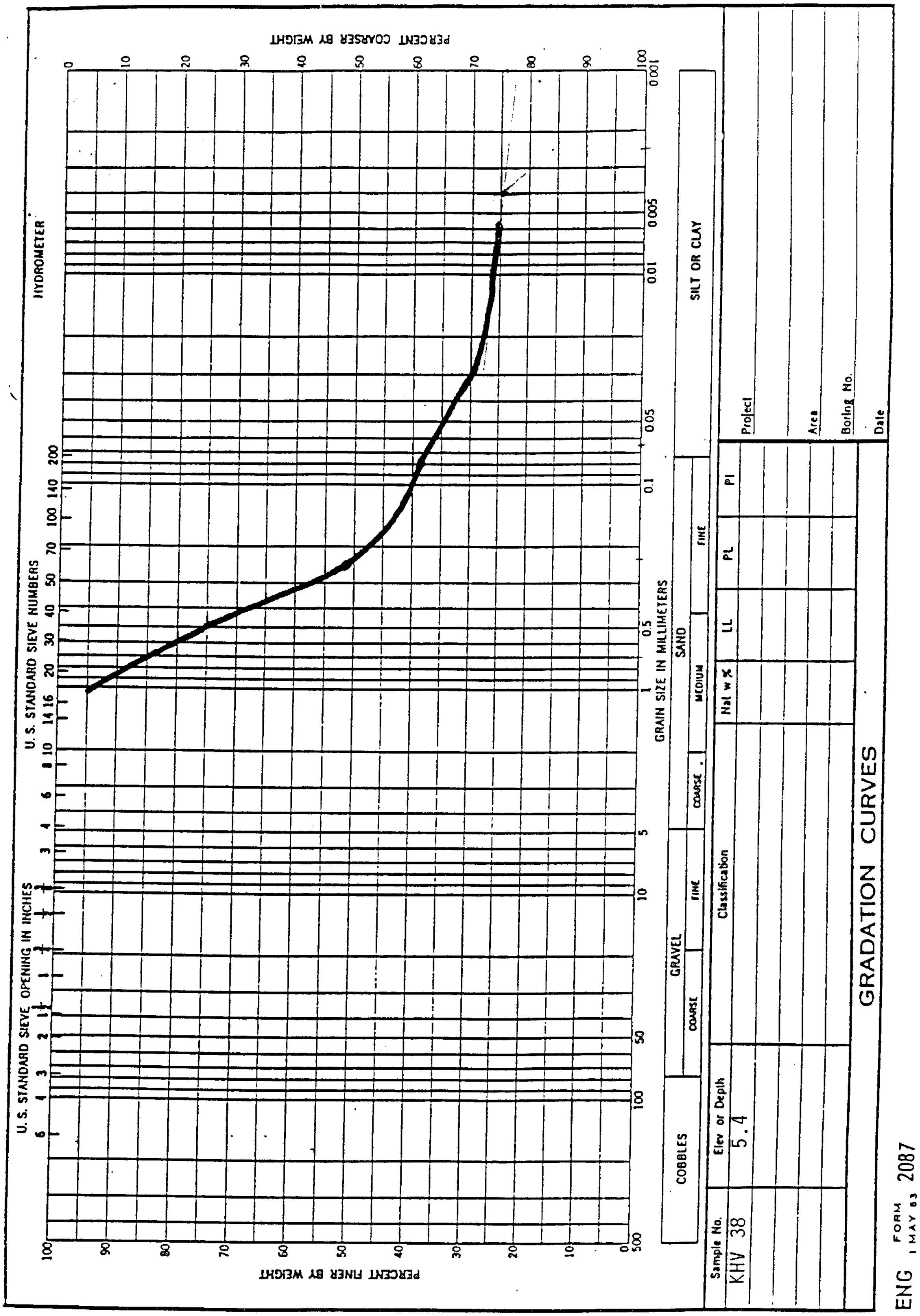
Drilling Log (Cont Sheet)	Elevation Top of Hole -48.6'	Hole No. KHV-38
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Dark gray, medium sand; trace round gravel; wet			Sample at 10.5'
	11–12	SP	Dark green-gray, medium to fine sand			
	13–17	SW, SW	Gray, coarse sand; some very coarse gravel; some silt			Sample at 14.0'
			17.4 ft Recovery			
	18					
	19					
	20					
	21					

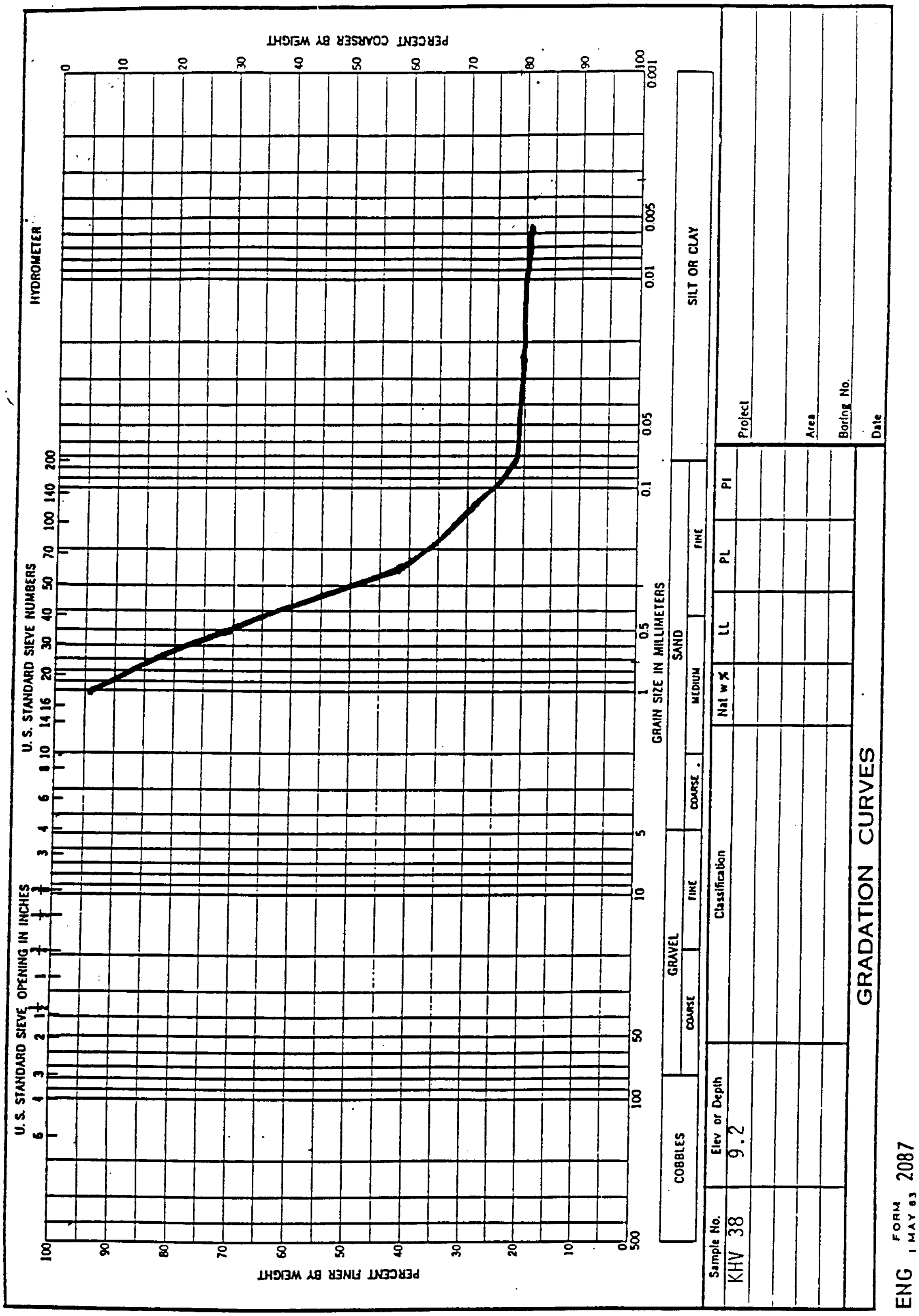
G FORM 1836 Project Hole No.



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 38
Elev or Depth
1.3
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
MEDIUM
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 38
5.4
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
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U. S. STANDARD SIEVE NUMBERS
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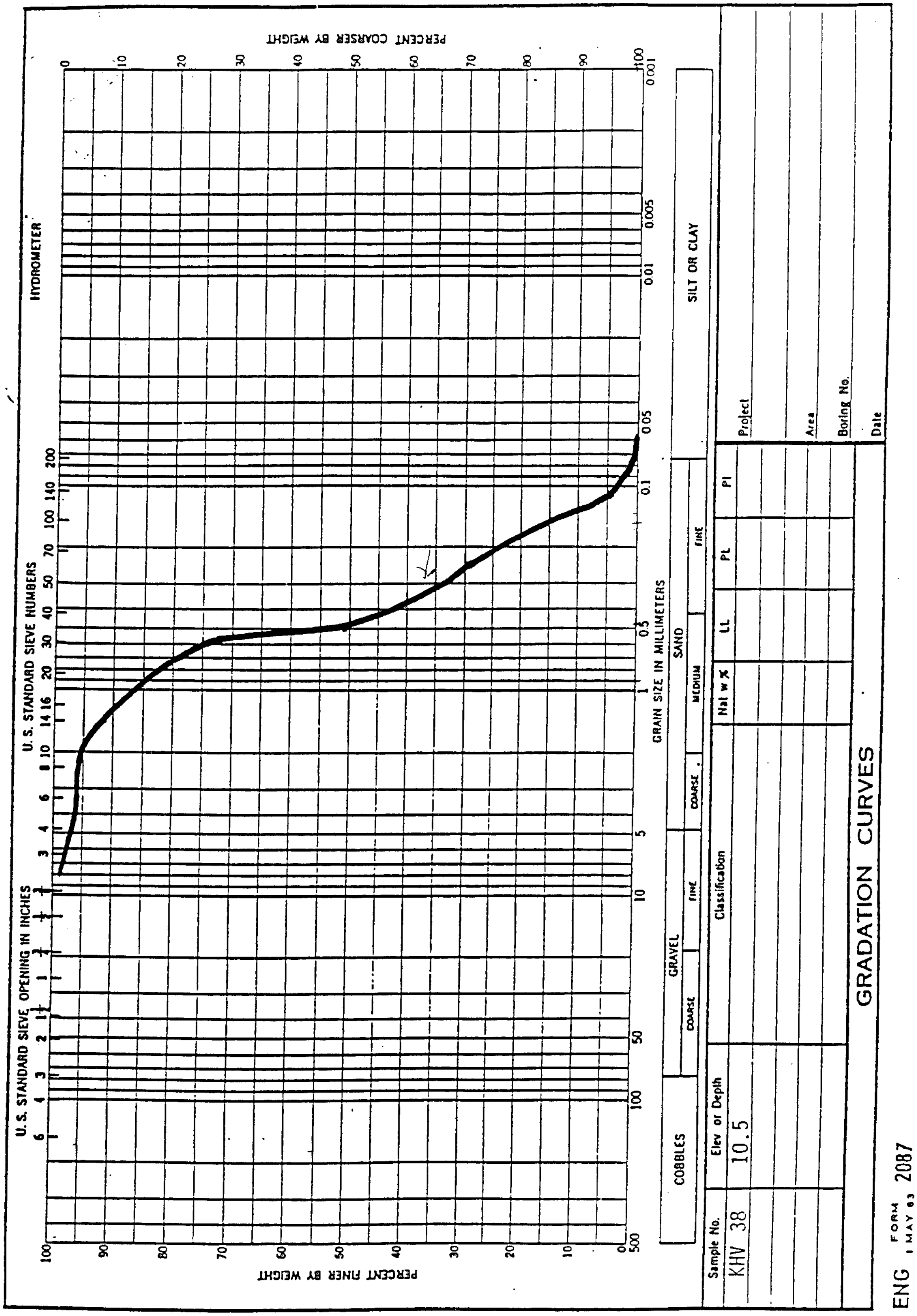
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 38
Elev or Depth
9.2
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



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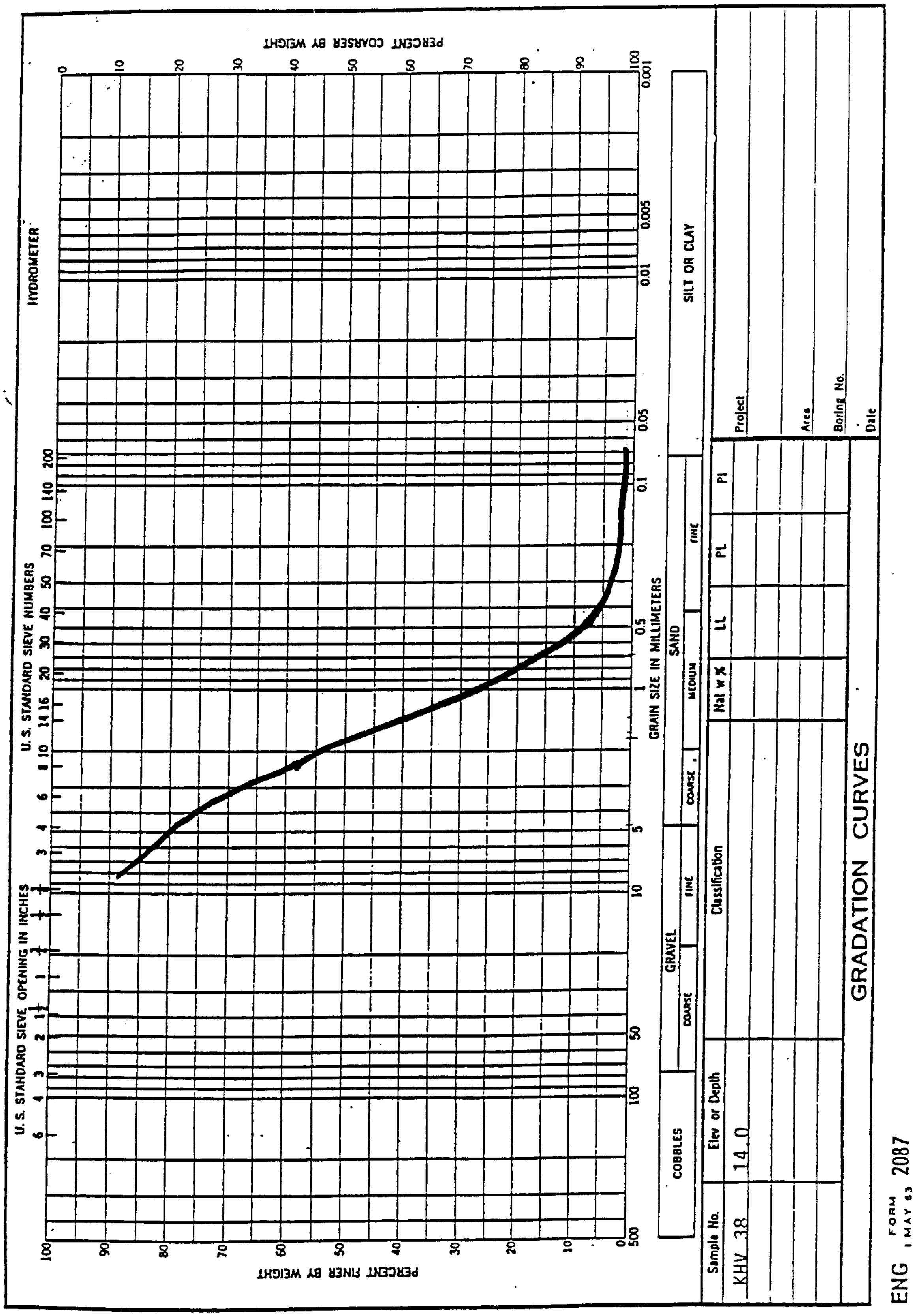
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 38
Elev or Depth
10.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 38
14.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 769929.89E, 247323.02N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-39	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/9/93 — Completed 6/9/93
7. Thickness of Overburden	17. Elevation Top of Hole -49.7'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 17.7 ft	19. Signature of Inspector JV D-JK

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–3	SC	Dark gray, wet, clayey sand	100		Sample at 2.0'
	3–3.5	SP	Brown silt and fine sand			
	3.5–5	SW	Gray, medium to fine sand with mud			
	5–7.8	SW	Gray, medium to fine sand with mud	100		Sample at 6.6'
	7.8–9.8	GP	Dark gray mud and gravel	100		
	9.8–10	SM	Dark gray muddy sand			

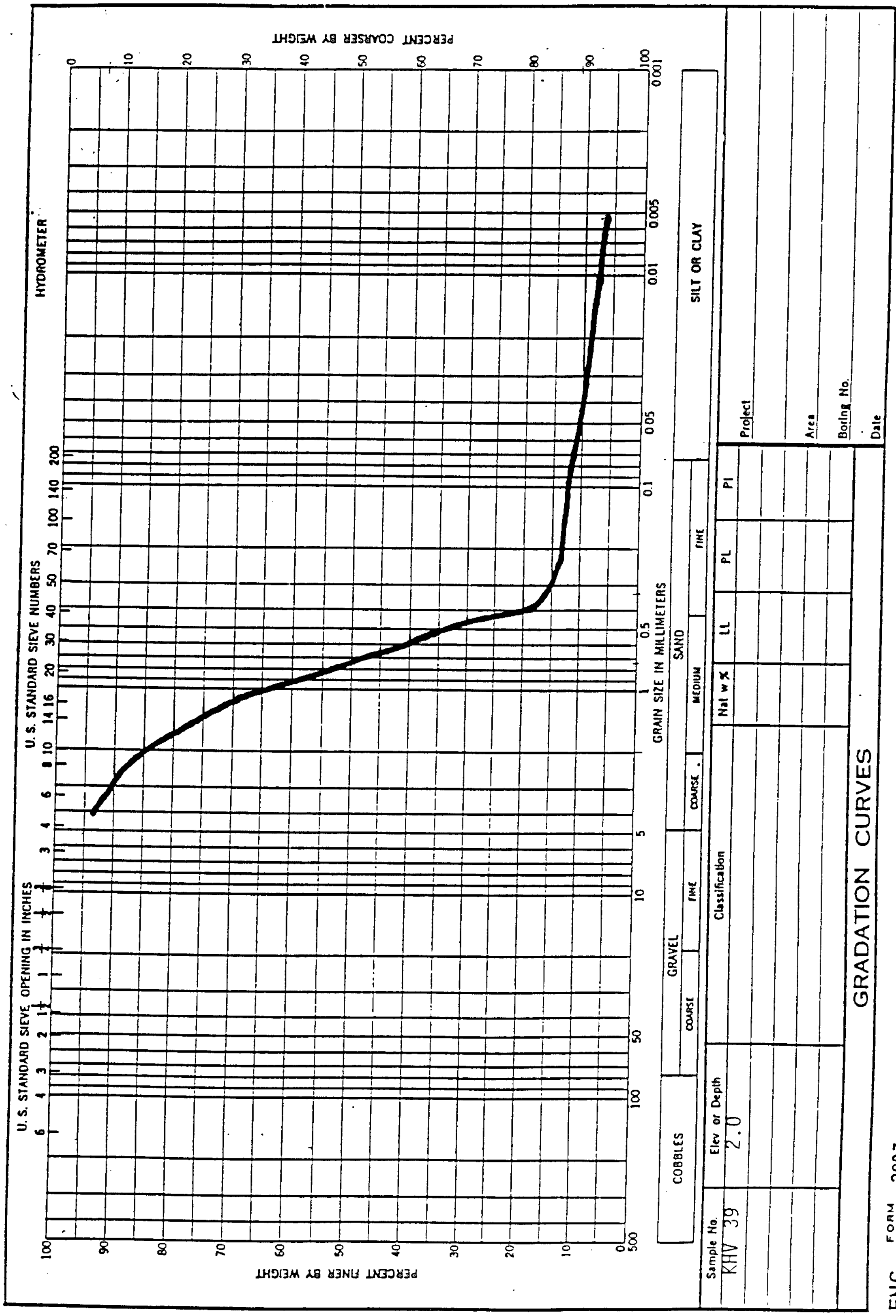
ENG FORM 1836 — Project — Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -49.7'	Hole No. KHV-39
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	11	GP	Gray, gravelly, medium sand			Sample at 11.0'
	12	GP	Light gray, gravelly coarse sand			
	13	GP	Brown, gravelly, sand			
	15	GP	Brown, gravelly sand			Sample at 15.0'
		SP	Light brown, medium sand			
	18		17.7 ft Recovery			

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

NG FORM 1836 Project Hole No.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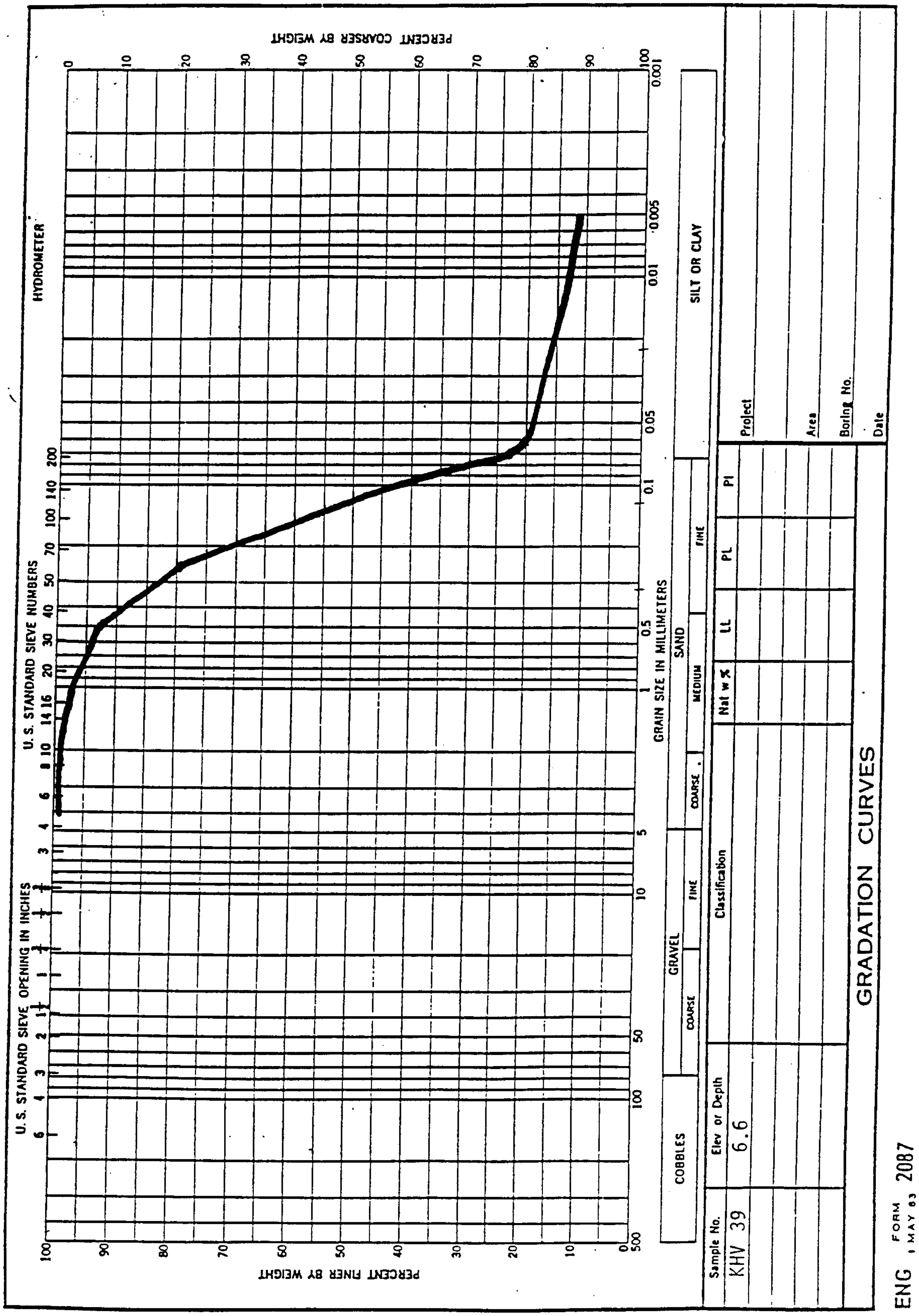
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No. KHV 39
Elev or Depth 2.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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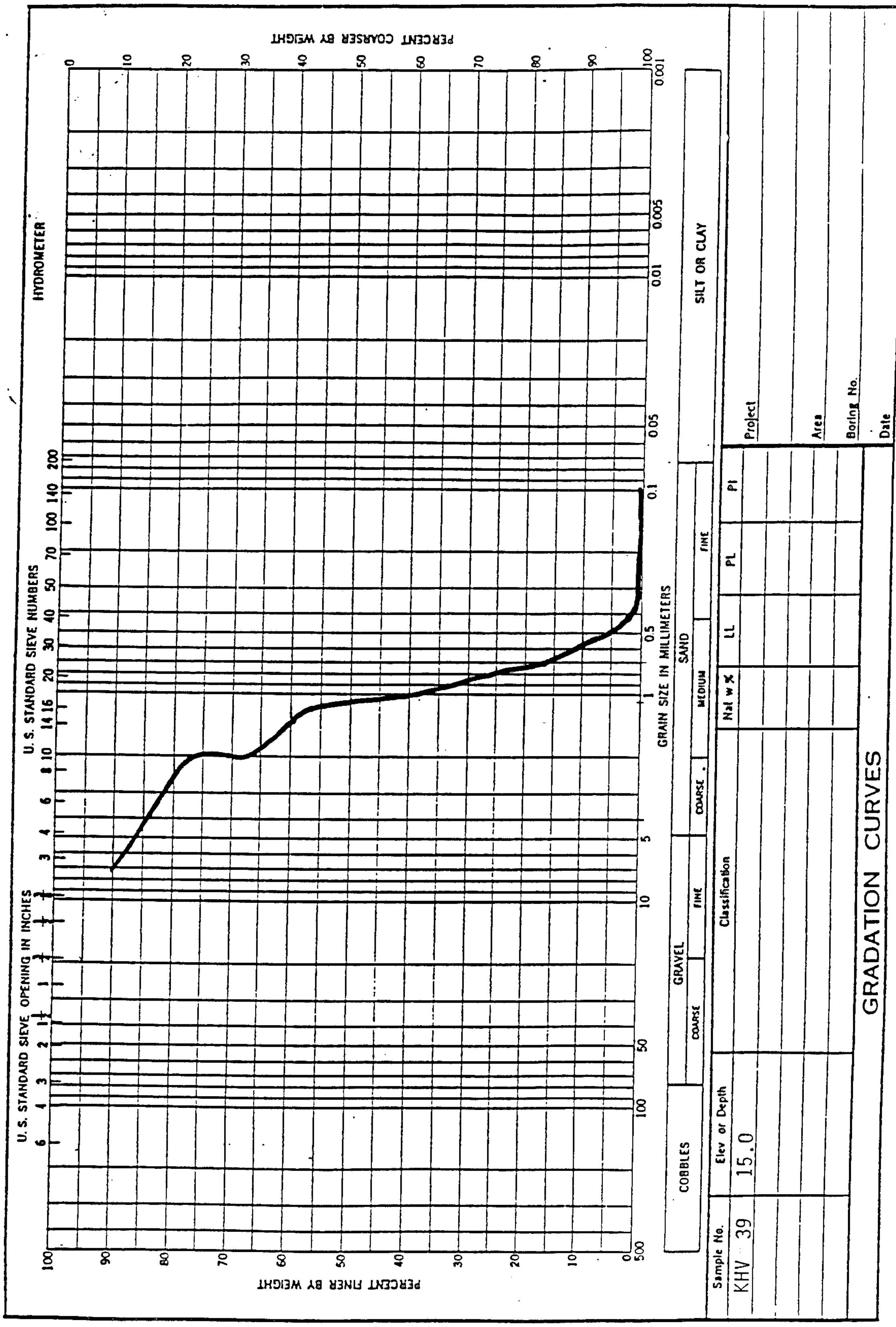
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 39
Elev or Depth
6.6
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 39
Elev or Depth
15.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

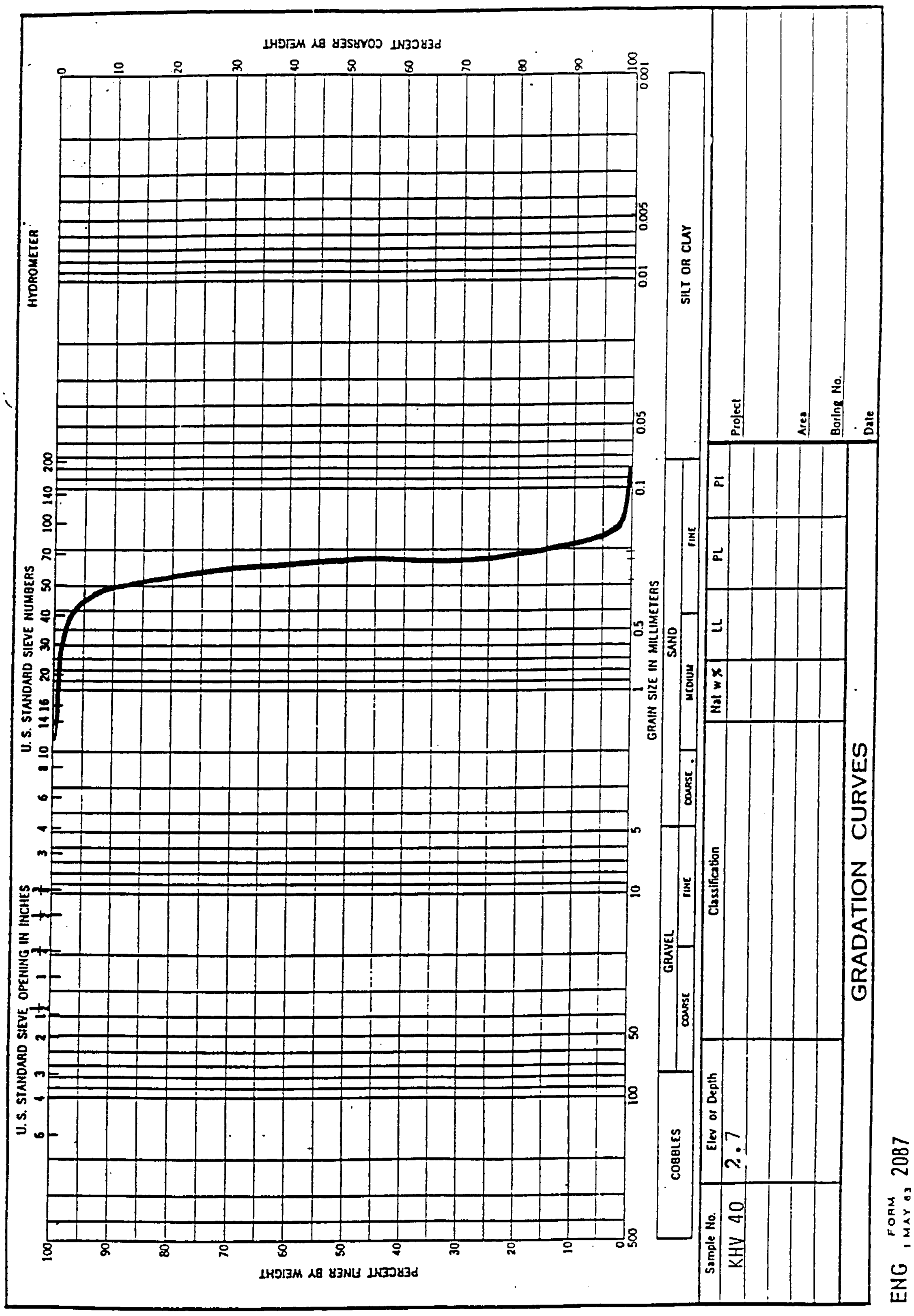
Drilling Log	
1. Project KHV	10. Size and Type of Bit
2. Location 767196.98E, 264982.80N	11. Datum for Elevation Shown (TDM or MSL) MLLW
. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-40	13. Total No. of Overburden Samples Taken — Disturbed: — Undisturbed:
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started 6/8/93 — Completed 6/8/93
	17. Elevation Top of Hole −30.5'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	19. Signature of Inspector JV GZ
9. Total Depth of Hole 19.7 ft	

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0					
	1	SP	Brown medium sand, becomes finer at 5'; some silt present 15'–20'			
	2					
	3					Sample at 2.7'
	4	SP	Brown medium sand			
	5					
	6					
	7					Sample at 7.5'
	8	SP	Brown-gray medium sand			
	9					
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -30.5'		Hole No. KHV-40			
Project KHV		Installation			Sheet 2 of 2 Sheets	
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11	SP	Brown-gray medium sand			
	12					
						Sample at 12.6'
	13					
	14	SP	Gray medium sand			
	15					
	16					
	17	SP	Gray medium sand			
						Sample at 17.5'
	18					
	19					
			19.7 ft Recovery			
	20					
	21					

NG FORM 1836 Project Hole No.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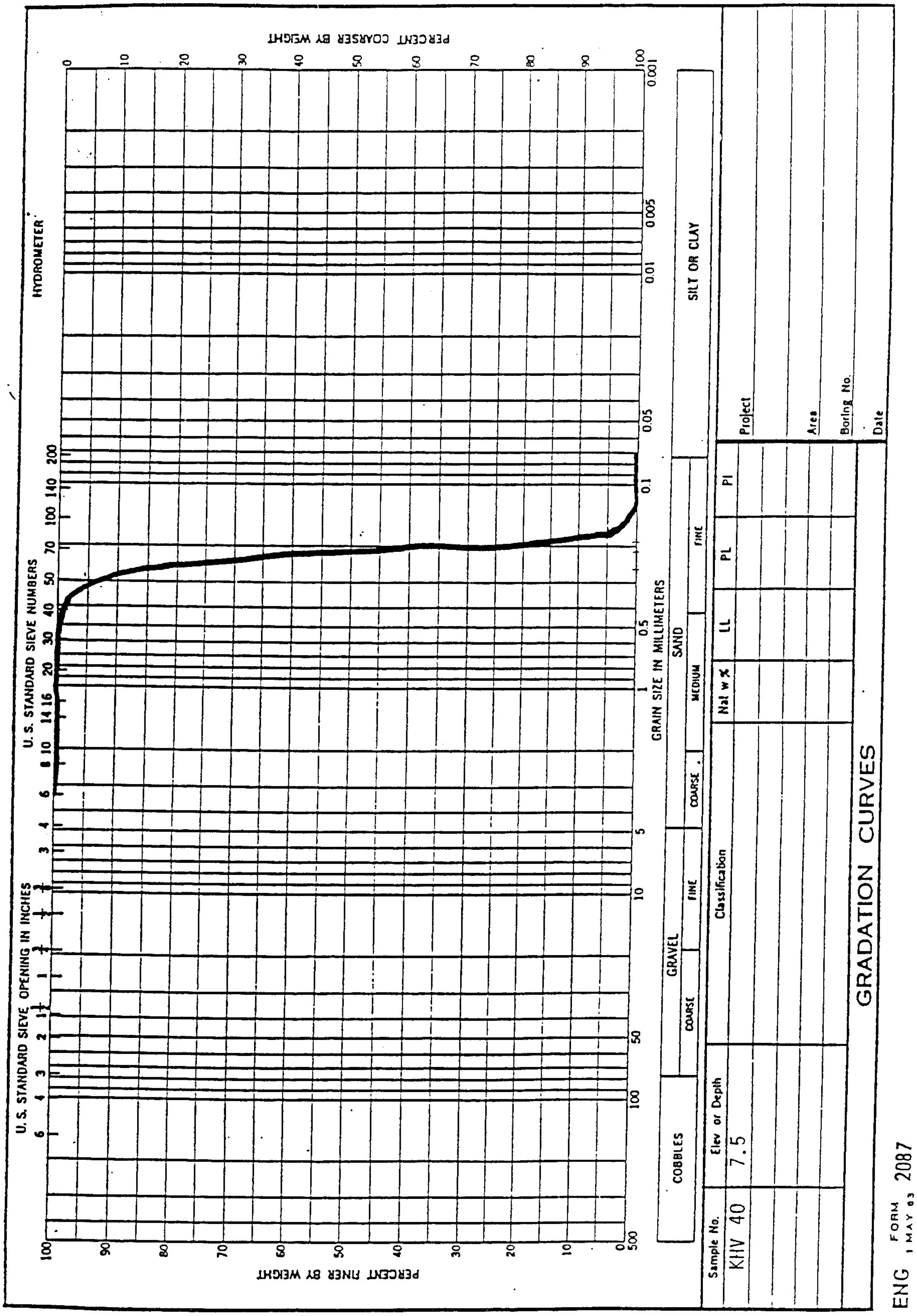
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 40
Elev or Depth
2.7
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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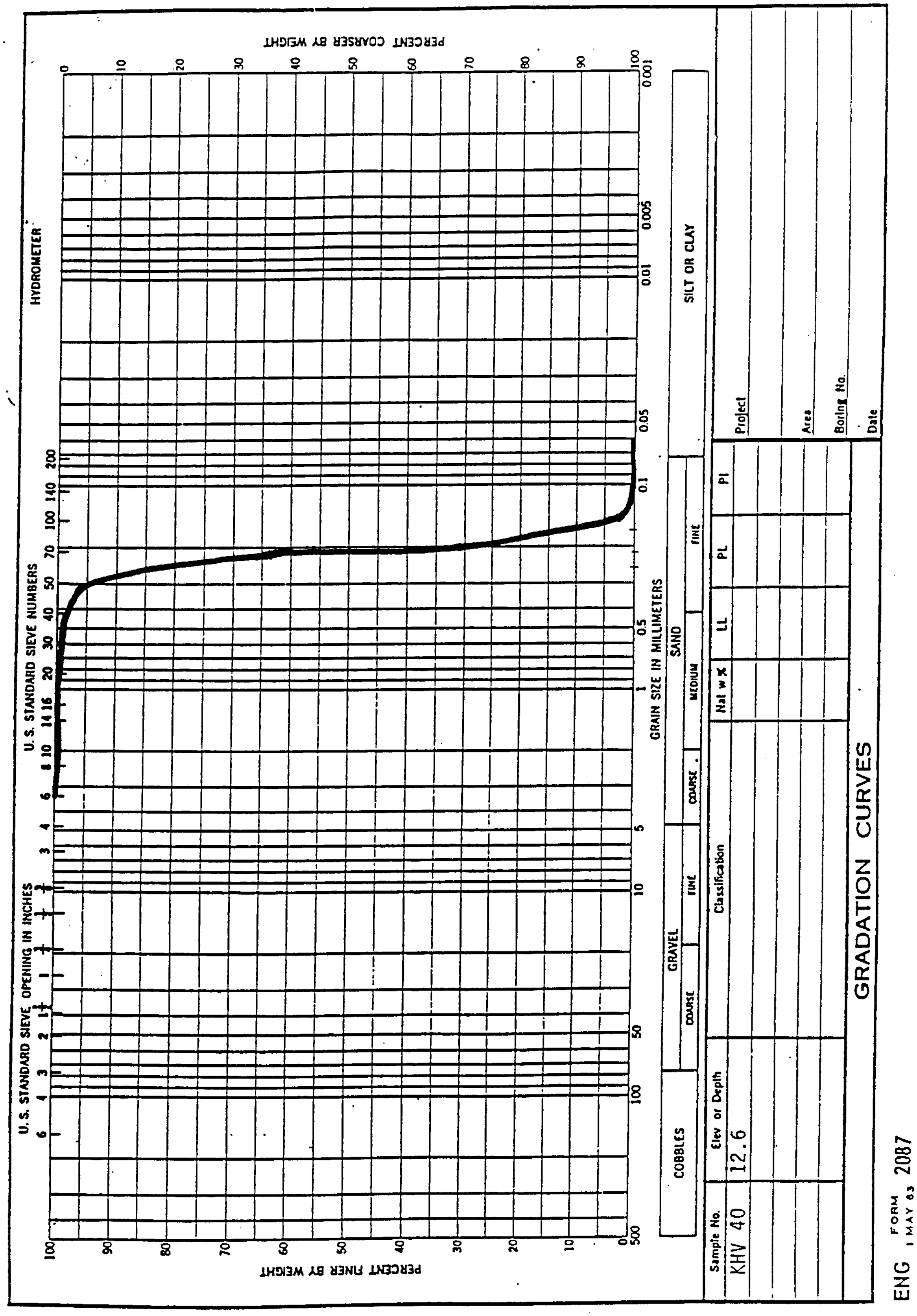
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 40
Elev or Depth
7.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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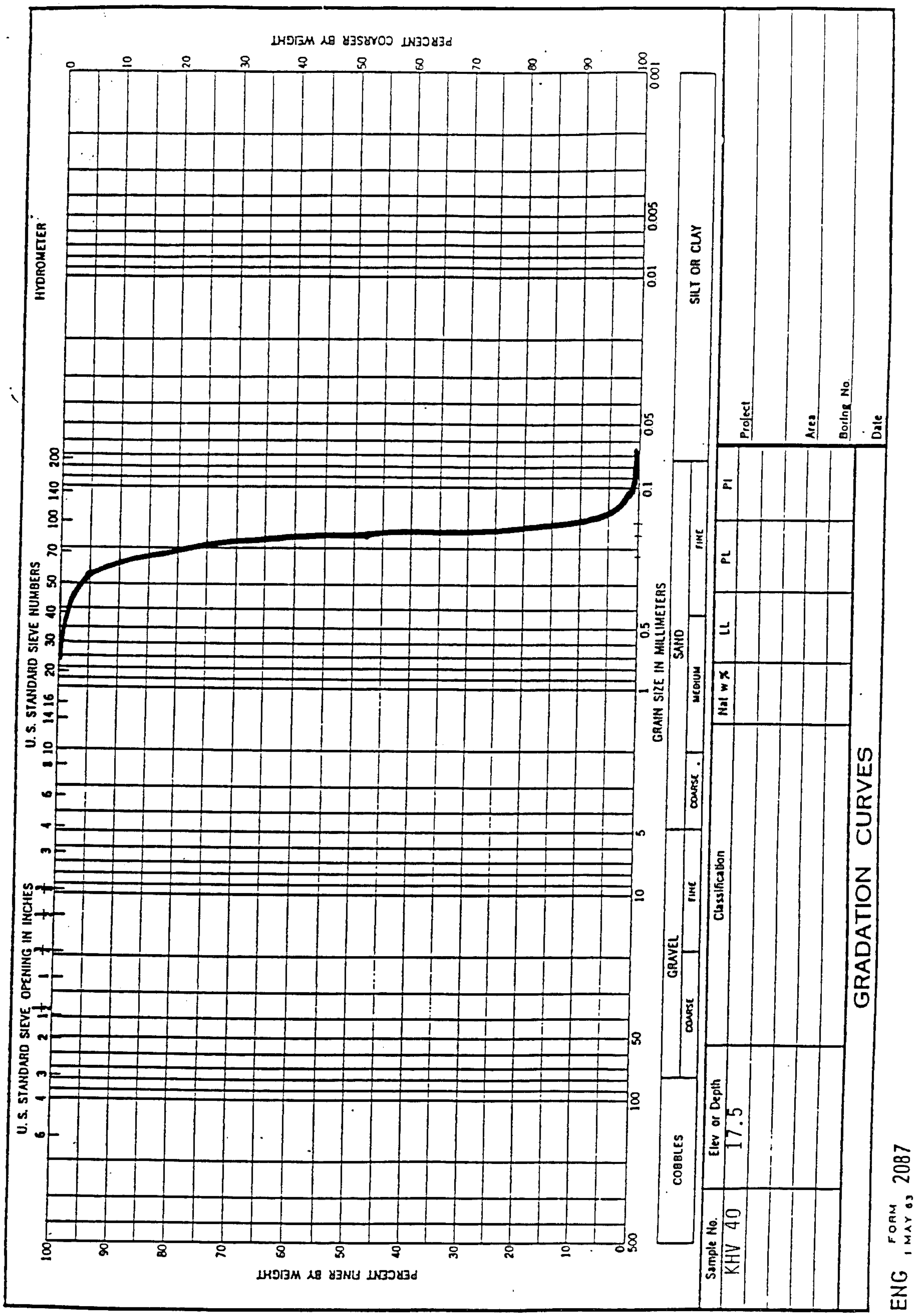
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 40
Elev or Depth
12.6
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 40
Elev or Depth
17.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 768958.59E, 263445.90N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-41	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started 6/8/93 — Completed 6/8/93
	17. Elevation Top of Hole -29.9'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	19. Signature of Inspector JV MC
9. Total Depth of Hole 19.9 ft	

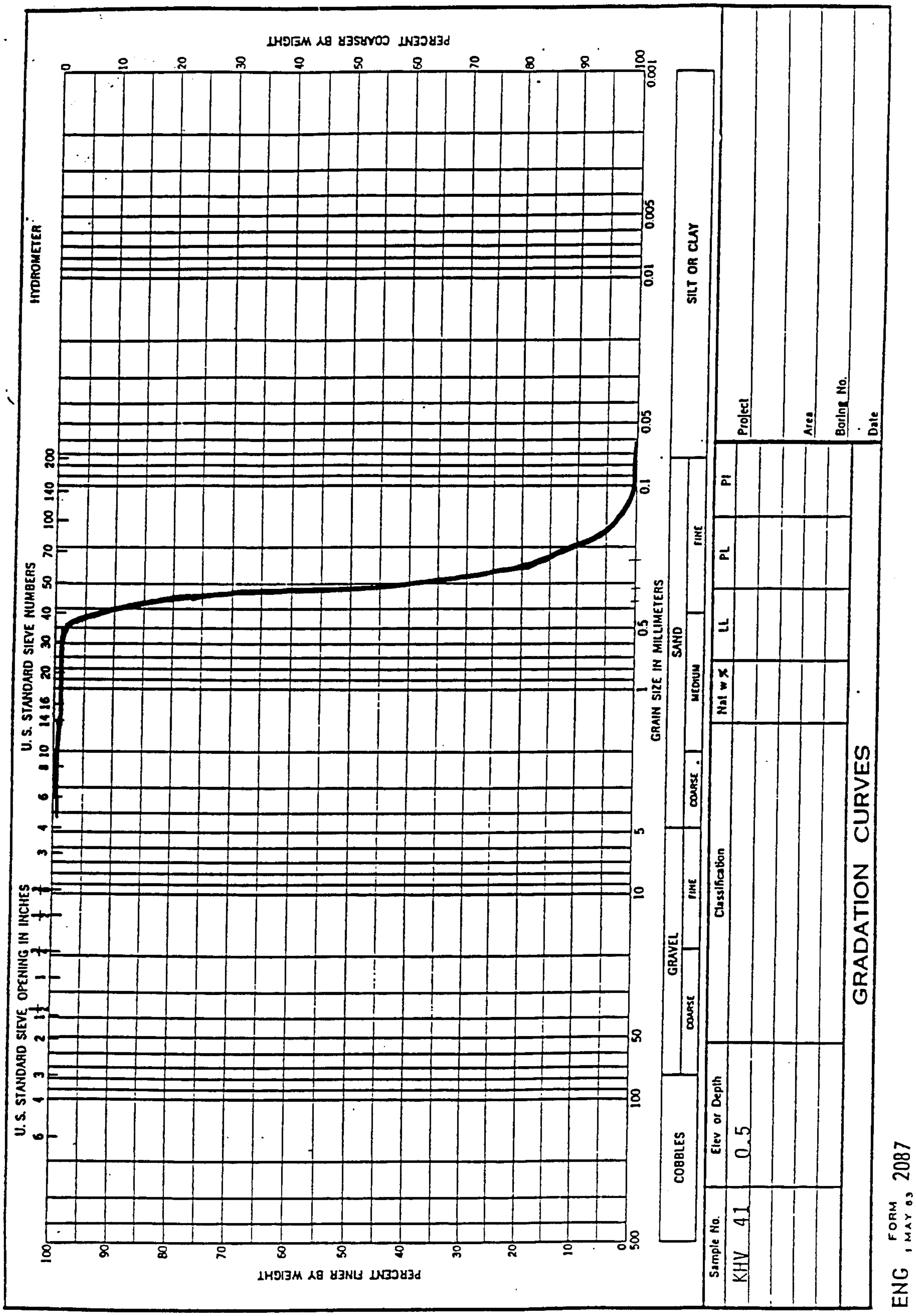
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if signficant) g
	0					
		SP	Medium brown sand with traces of shell			Sample at 0.5'
	1					
	2					
		SP	Gray-brown sand, clay lenses present, traces of FE oxide			
	3					Sample at 3.2'
	4					
			Brown, fine to medium sand			Sample at 4.6'
	5	SP				
	6					
			Gray medium sand, 6.4'–10'			
	7					Sample at 7.1'
	8	SP				
	9					
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -29.9'		Hole No. KHV-41
Project KHV	Installation		Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Brown, fine to medium sand			Sample at 10.5'
	11					
	12	SP	Dark gray, fine to medium sand			
	13	SP	Dark gray, fine to medium sand			Sample at 13.2'
	14	SP	Light brown, medium sand			
	15					
	16					
	17	SP	Light brown to gray, medium sand			Sample at 17.0'
	18					
	19	SP	Alternating bands of gray and light brown medium sand			
			19.9 ft Recovery			
	20					
	21					

ENG FORM 1836 Project Hole No.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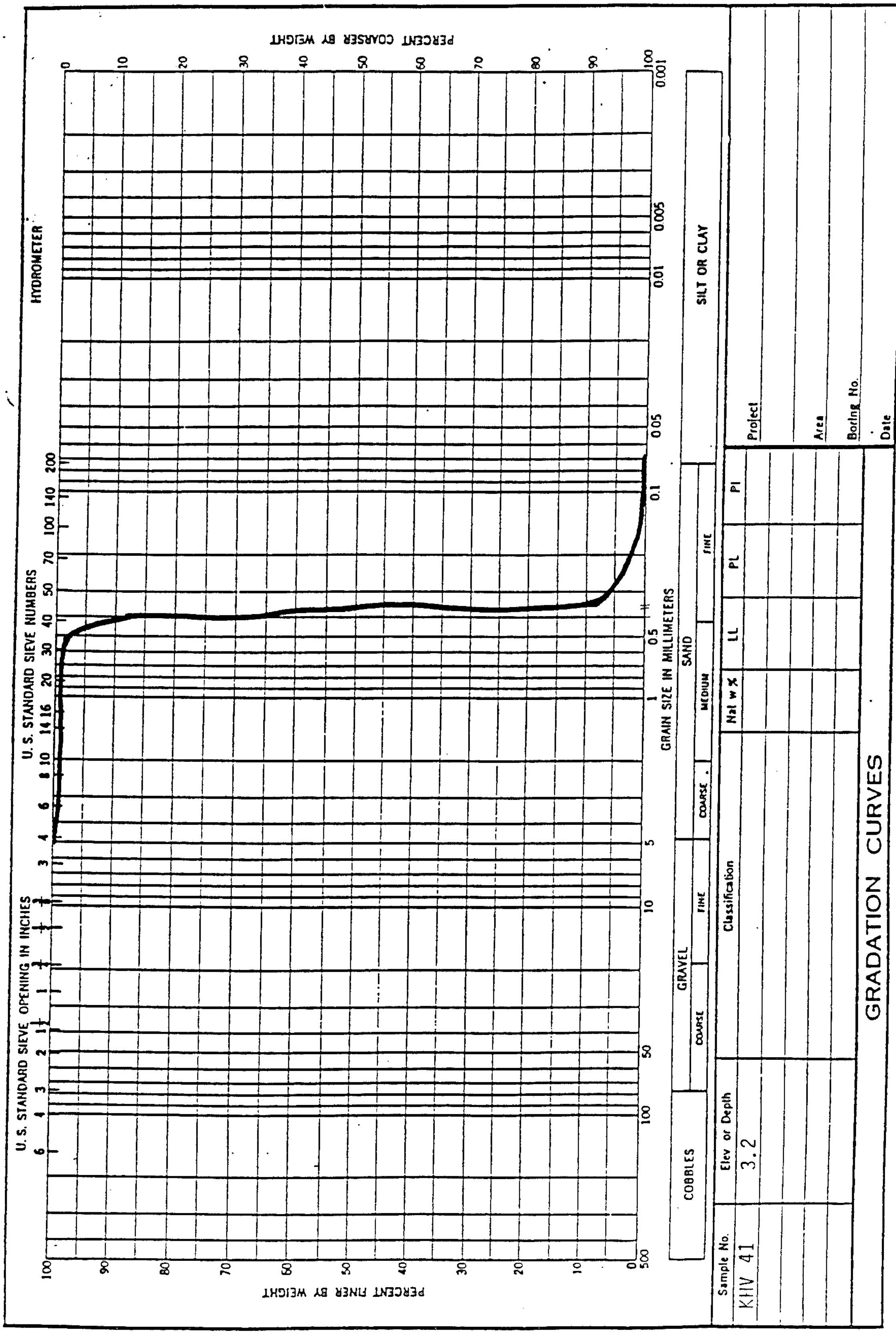
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 41
Elev or Depth
0.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



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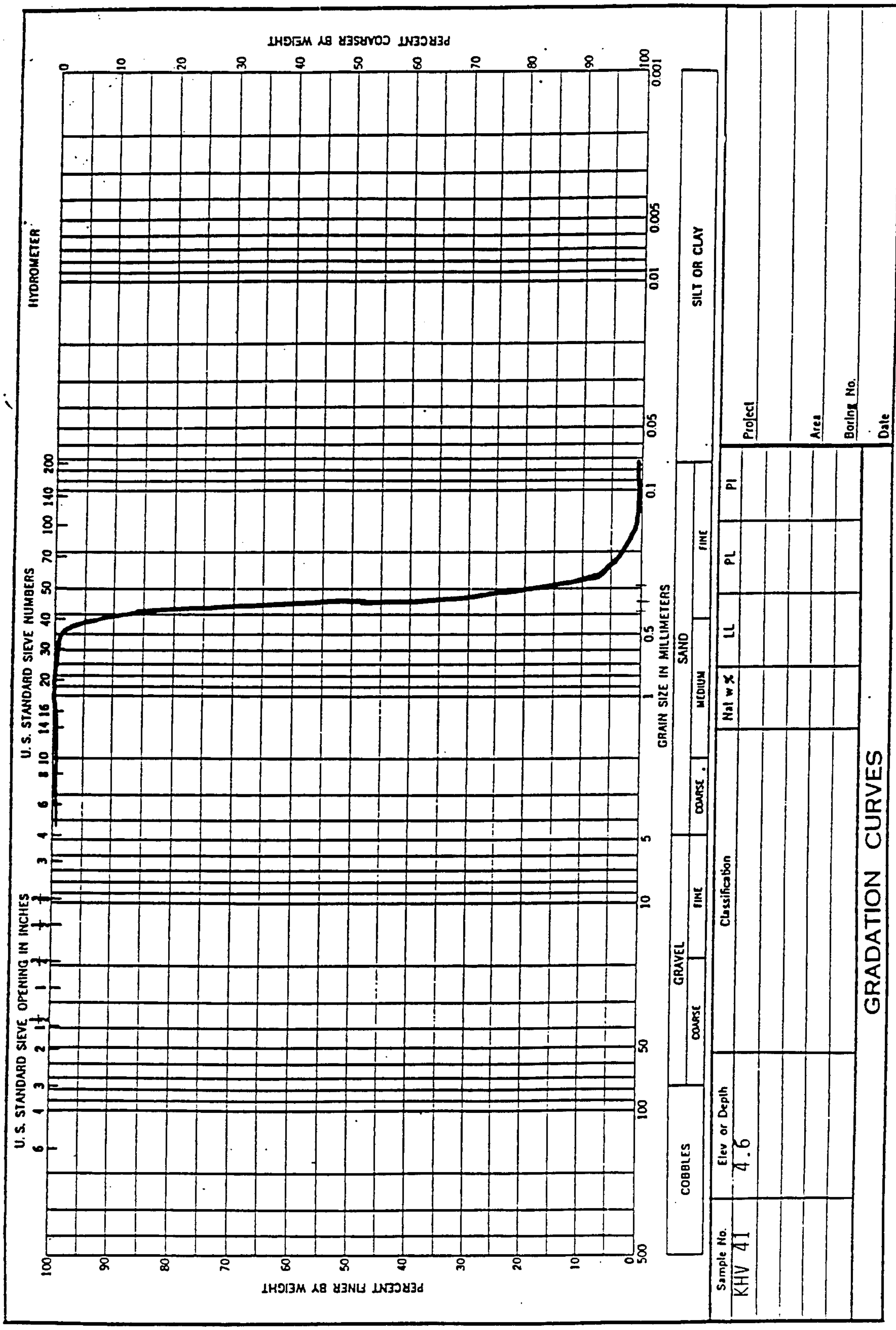

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PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 41
Elev or Depth
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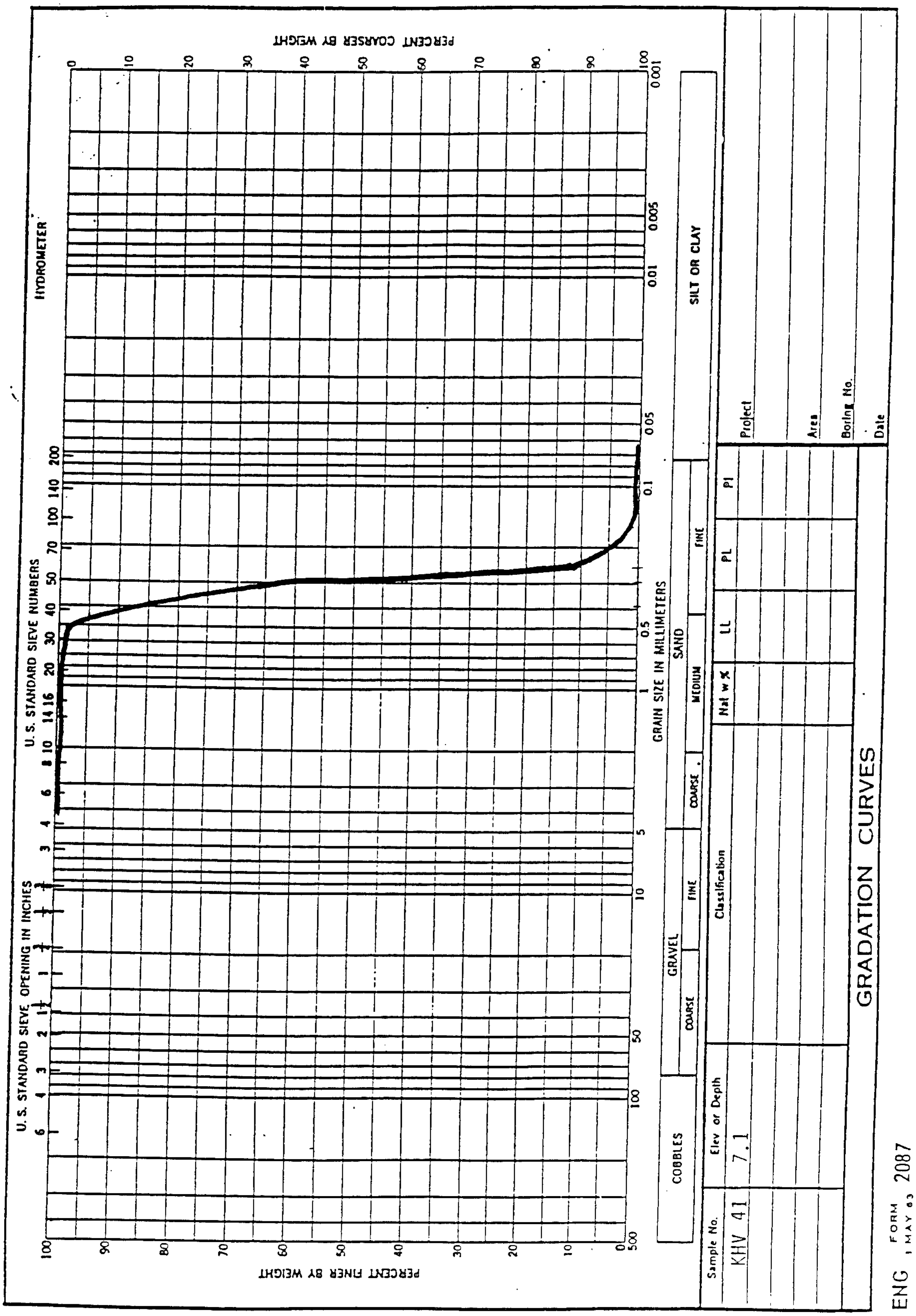
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
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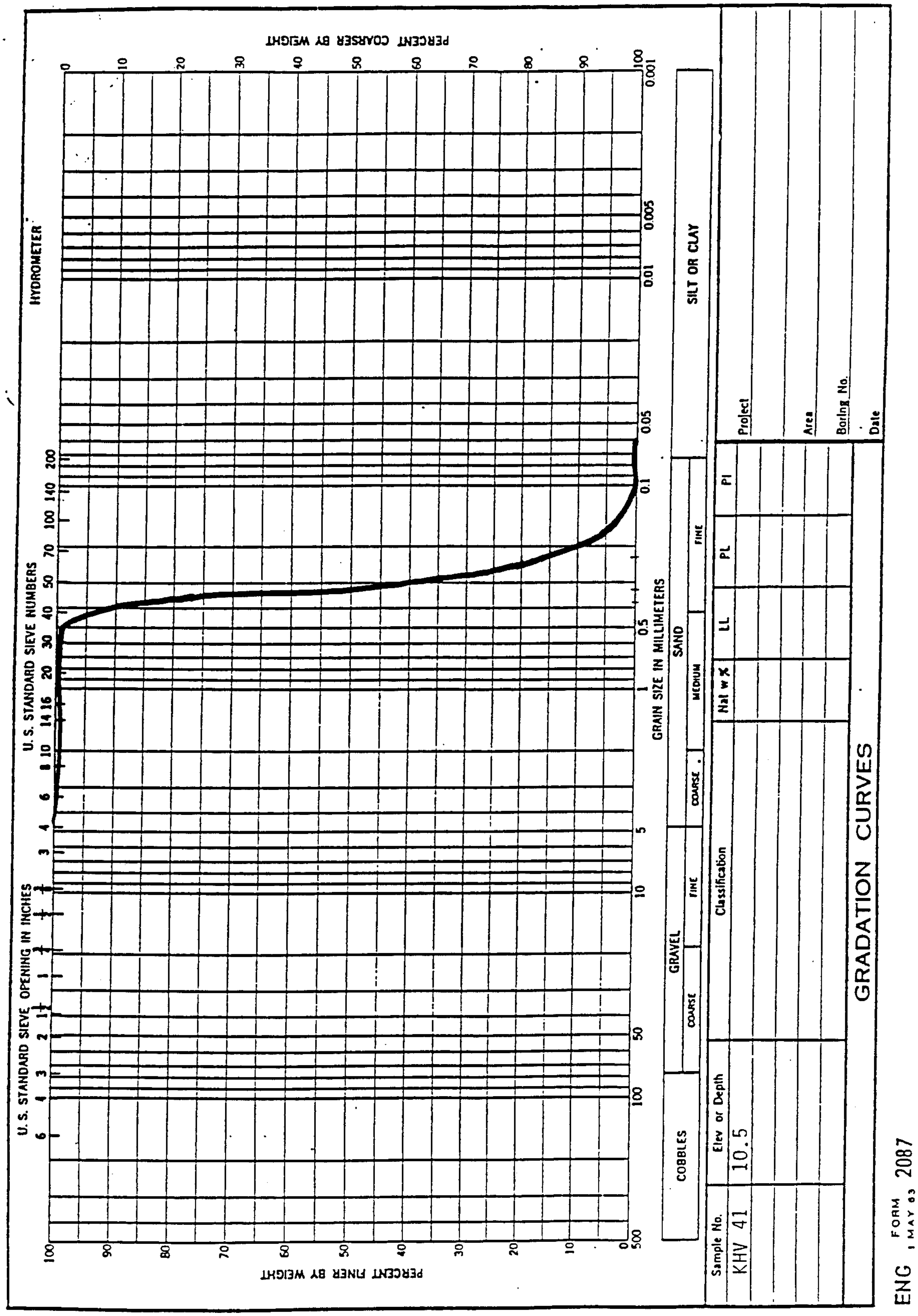
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 41
Elev or Depth
7.1
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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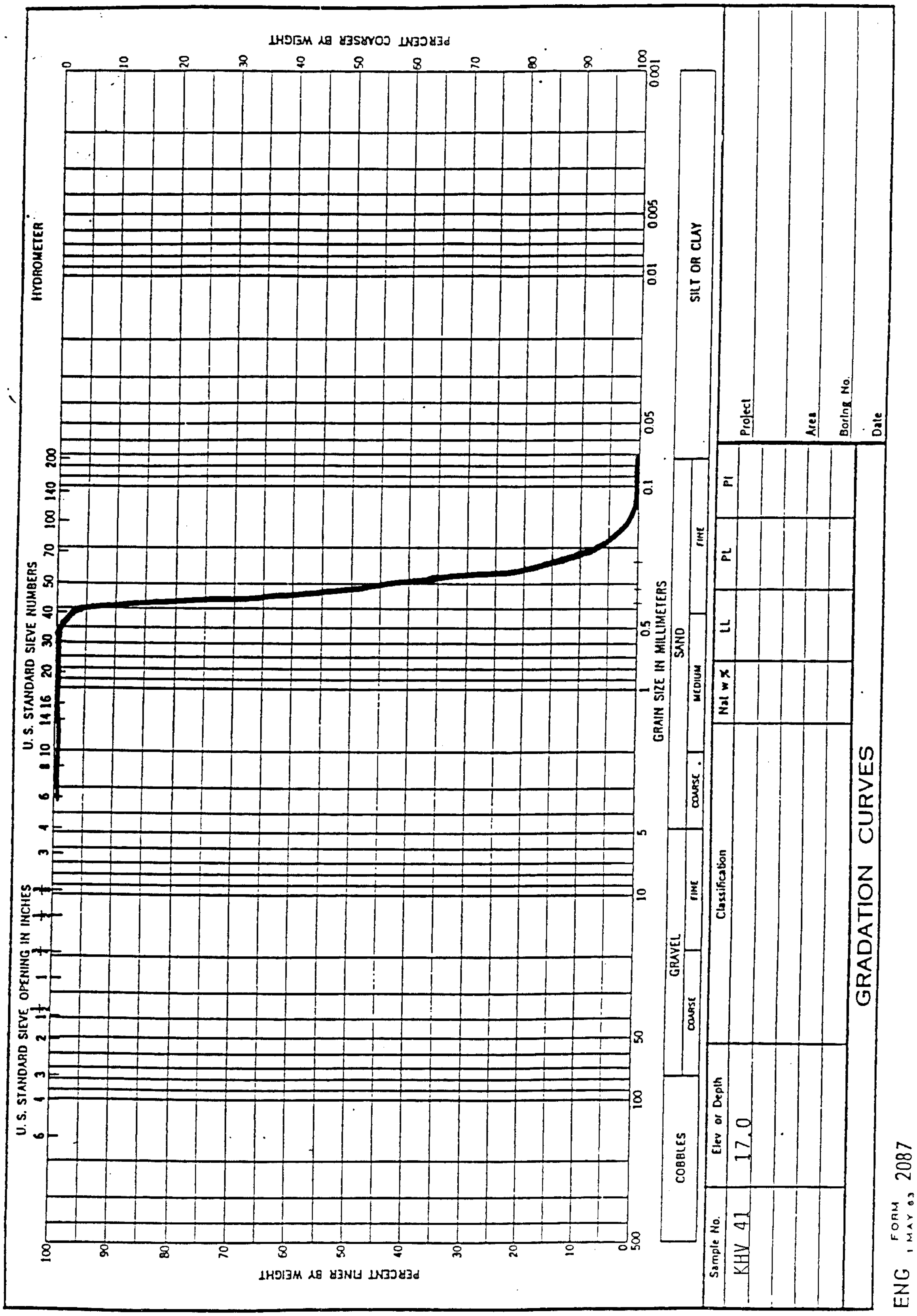
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 41
Elev or Depth
10.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 41
Elev or Depth
17.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 773836.00E, 233513.10N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-42	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	16. Date Hole — Started 6/9/93 — Completed 6/9/93
	17. Elevation Top of Hole -42.8'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	19. Signature of Inspector JV GZ
9. Total Depth of Hole 17.4 ft	

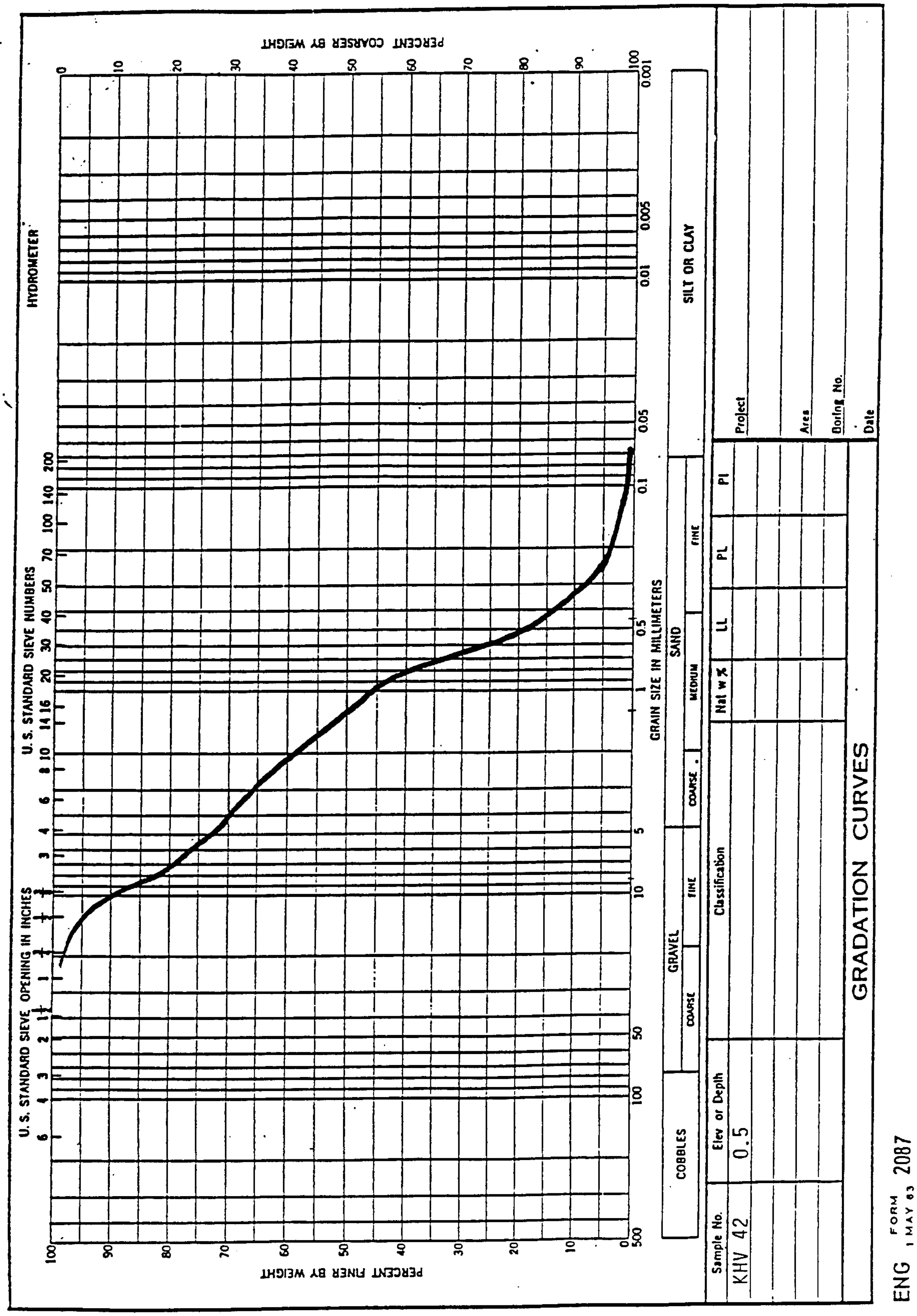
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if signficant) g
	0	SW	Dark gray, coarse sand and gravel; well graded	100		Sample at 0.5'
	1	SW	Light tan, silty, coarse sand and gravel; well graded			
	2					
	3		Light tan, medium sand and gravell; well graded			
	4			100		
	5	SW				Sample at 5.4'
	6					
	7					
	8	SW	Gray, medium sand and trace of gravel			Sample at 7.9'
	9			100		
		SP	Gray, medium sand			Sample at 9.2'
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -42.8'	Hole No. KHV-42
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray, medium sand			
	11 12 13	SW	Tan, medium to coarse sand; well graded			Sample at 12.8'
	14 15 16 17	GP	Tan, coarse sand and gravel Tan to light gray, medium sand 17.4 ft Recovery			Sample at 17.0'
	18 19 20 21					

ENG FORM 1836 Project Hole No.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U. S. STANDARD SIEVE NUMBERS
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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 42
Elev or Depth
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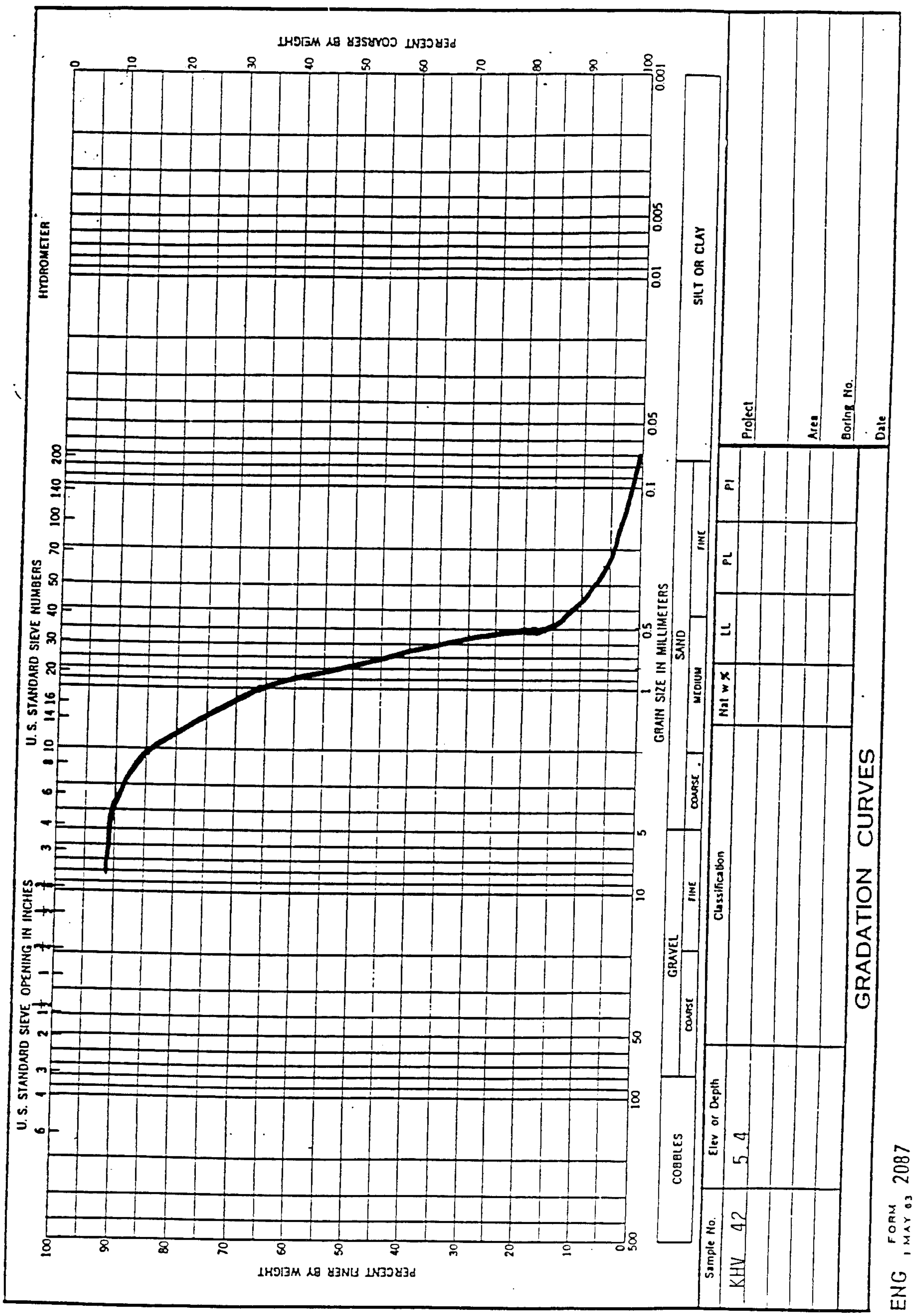
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
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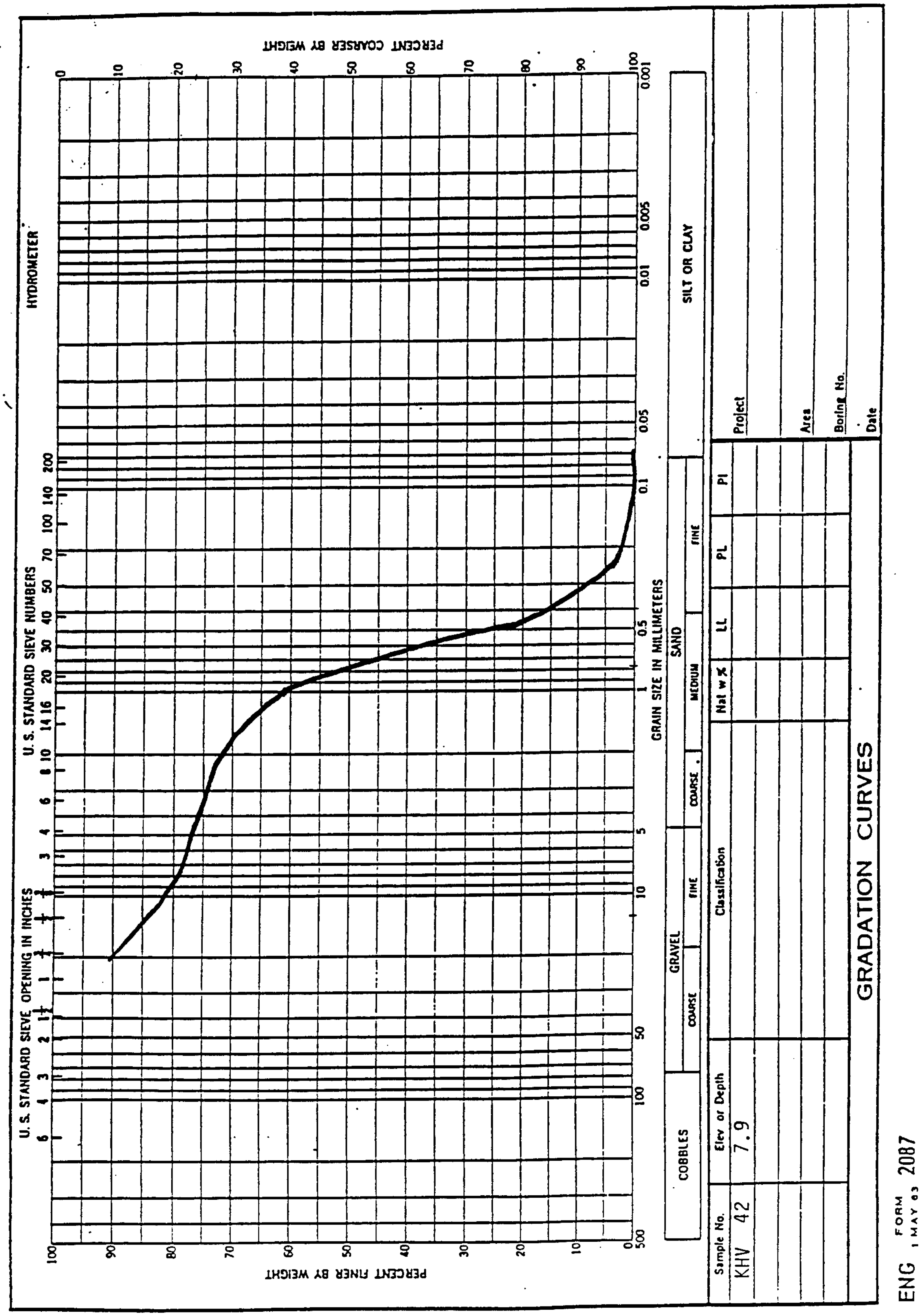
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 42
5.4
ENG FORM 1 MAY 63 2087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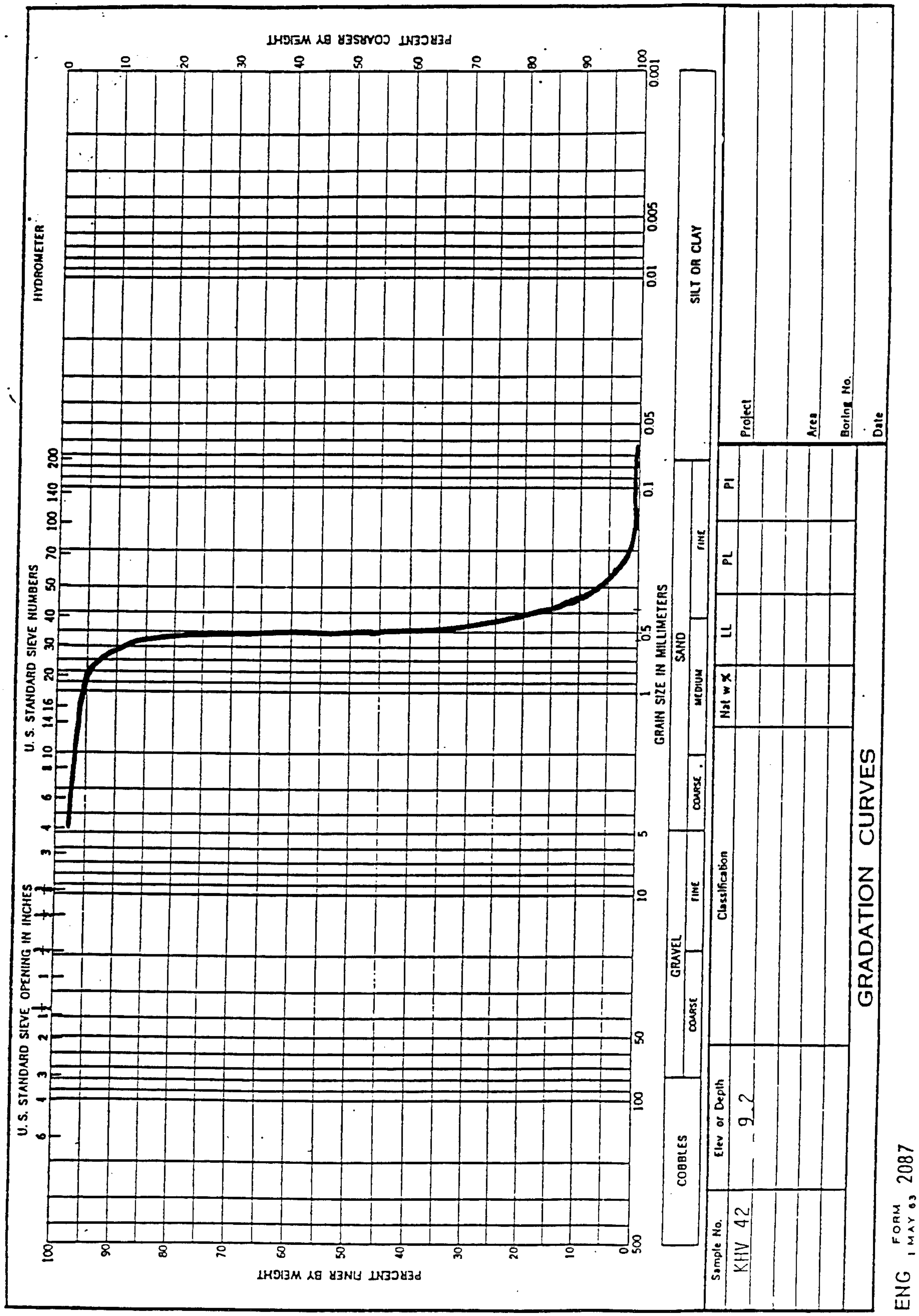
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 42
Elev or Depth
7.9
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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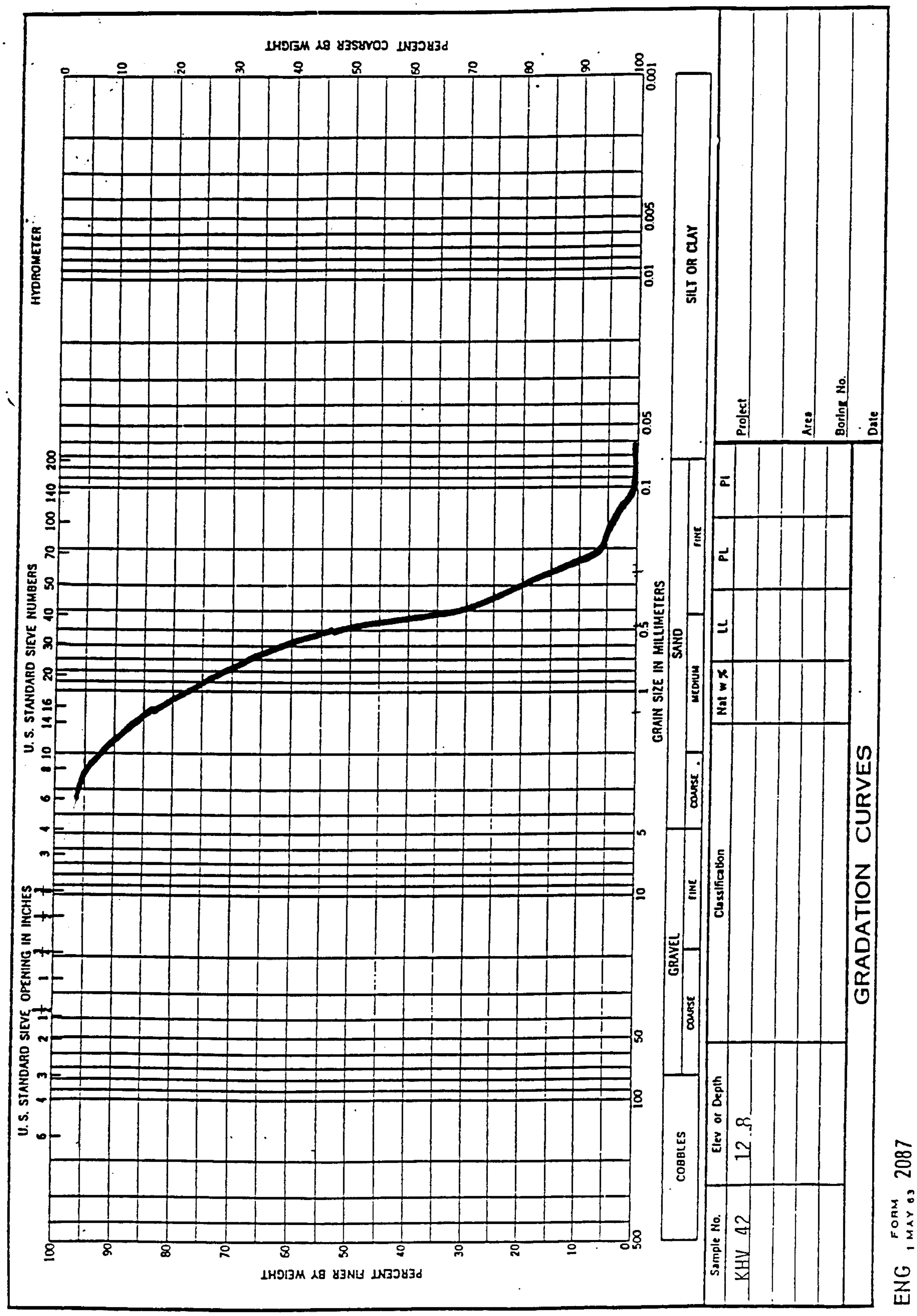
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 42
Elev or Depth
9.2
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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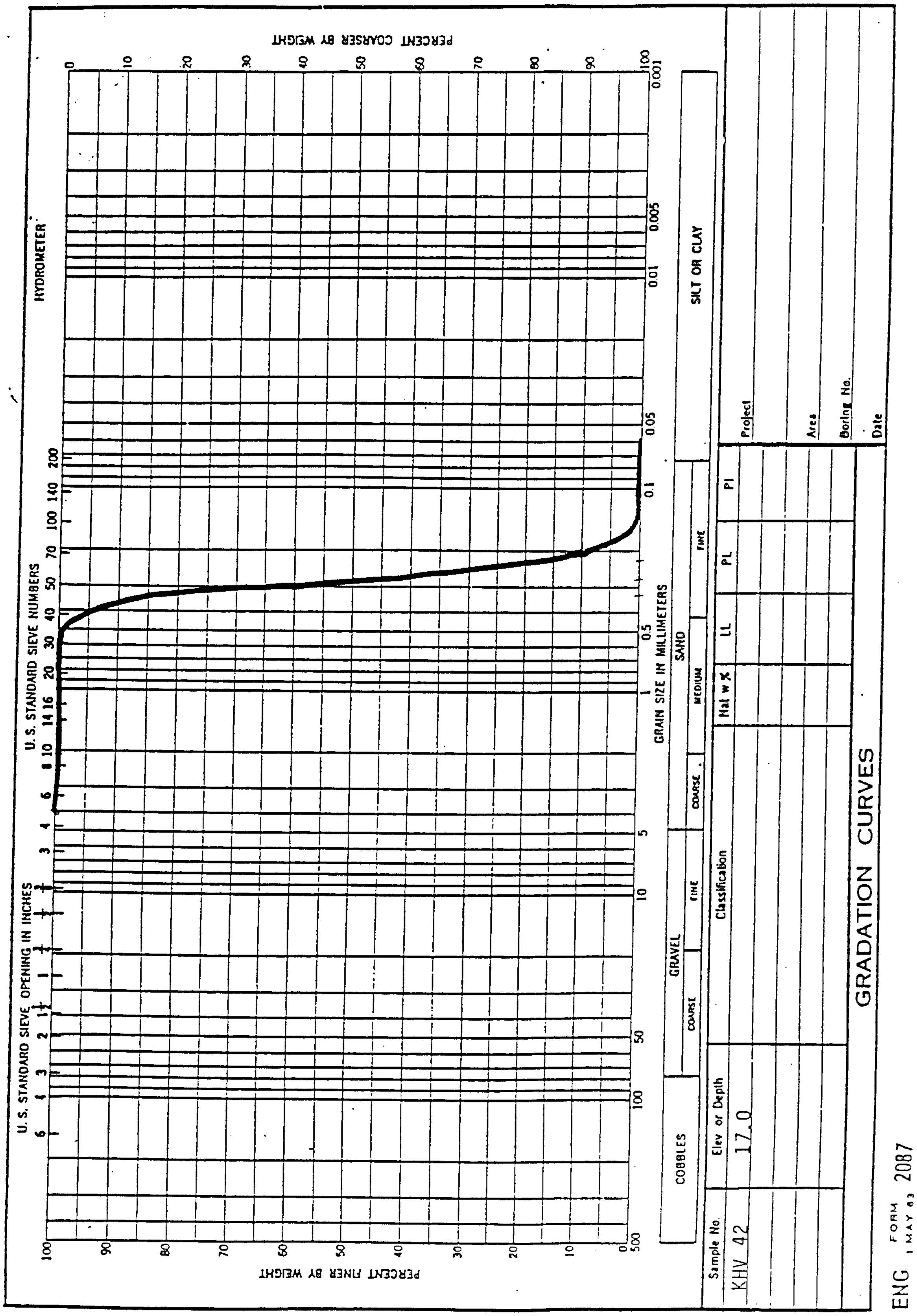
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 42
Elev or Depth
12.8
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 42
Elev or Depth
17.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log	1 of 2 Sheets
1. Project KHV	10. Size and Type of Bit
2. Location 762031.60E, 200531.00N	11. Datum for Elevation Shown (TDM or MSL) MLLW
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-44	13. Total No. of Overburden Samples Taken — Disturbed: — Undisturbed:
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
7. Thickness of Overburden	16. Date Hole — Started 6/13/93 — Completed 6/13/93
8. Depth Drilled into Rock	17. Elevation Top of Hole -28.1'
9. Total Depth of Hole 18.5 ft	18. Total Core Recovery for Boring %
	19. Signature of Inspector JV GZ

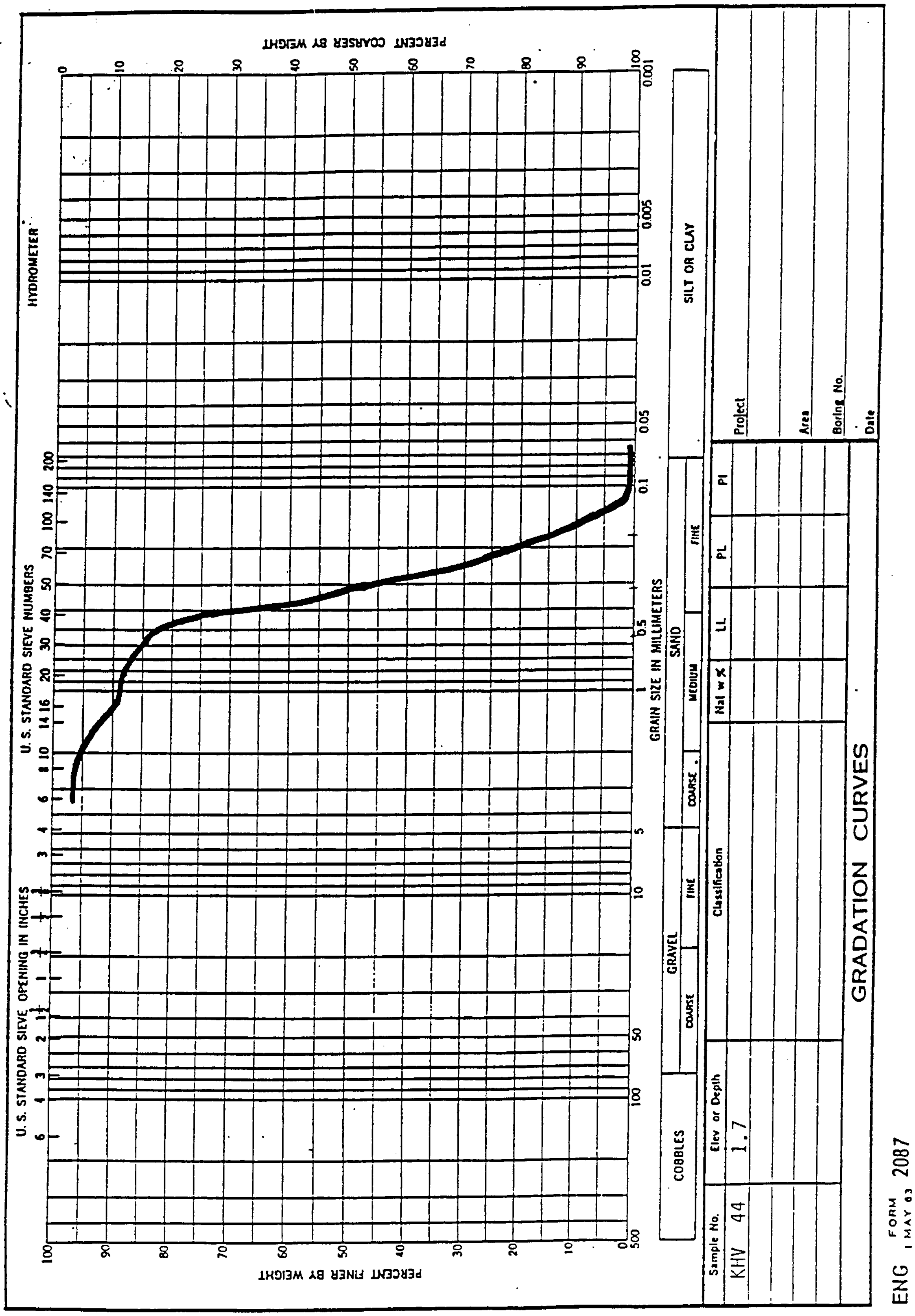
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–1	SP	Brown, fine to medium sand			
	1.7					Sample at 1.7'
	3		Gray to brown, fine to medium sand			
	5	SP	Gray to brown, fine sand with trace of mud			
	6.8					Sample at 6.8'
	8	SP	Light brown, coarse sand			Sample at 8.0'
	10					Sample at 10.0'

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -28.1'	Hole No. KHV-44
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray, medium sand			
	11					
	12					
	13	SP	Gray, medium sand			Sample at 13.0'
	14					
	15	CL	Dark brown, silty clay			
	16					
	17	SP	Gray, coarse sand Brown, fine sand and clay			Sample at 17.0'
	18					Sample at 18.5'
	19	SP	Silty, fine sand			
	20	SP	Medium to fine sand			Sample at 20.0'
			20.2 ft Recovery			
	21					

NG FORM 1836 Project Hole No.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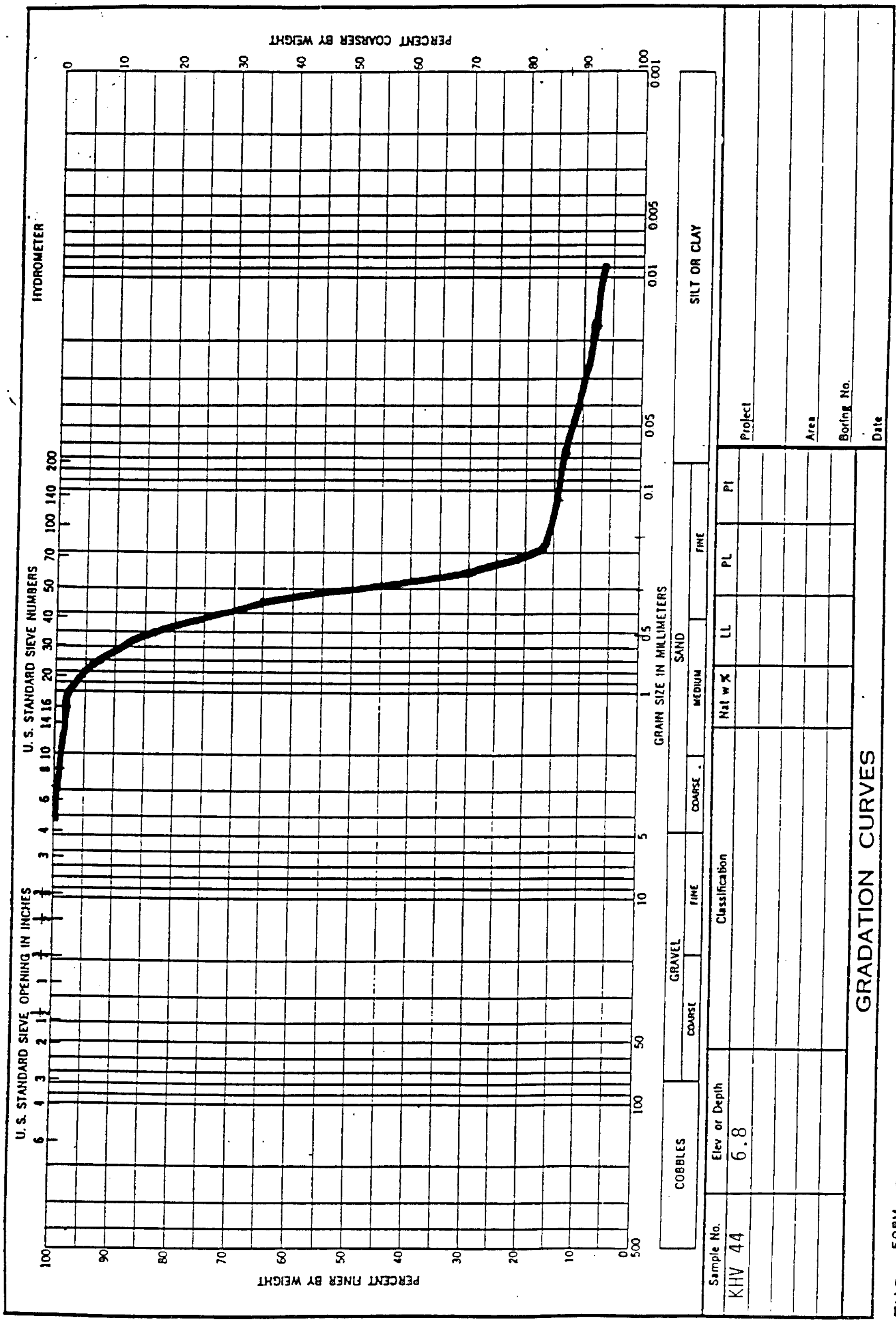
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 44
Elev or Depth
1.7
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



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U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 44
Elev or Depth
6.8
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

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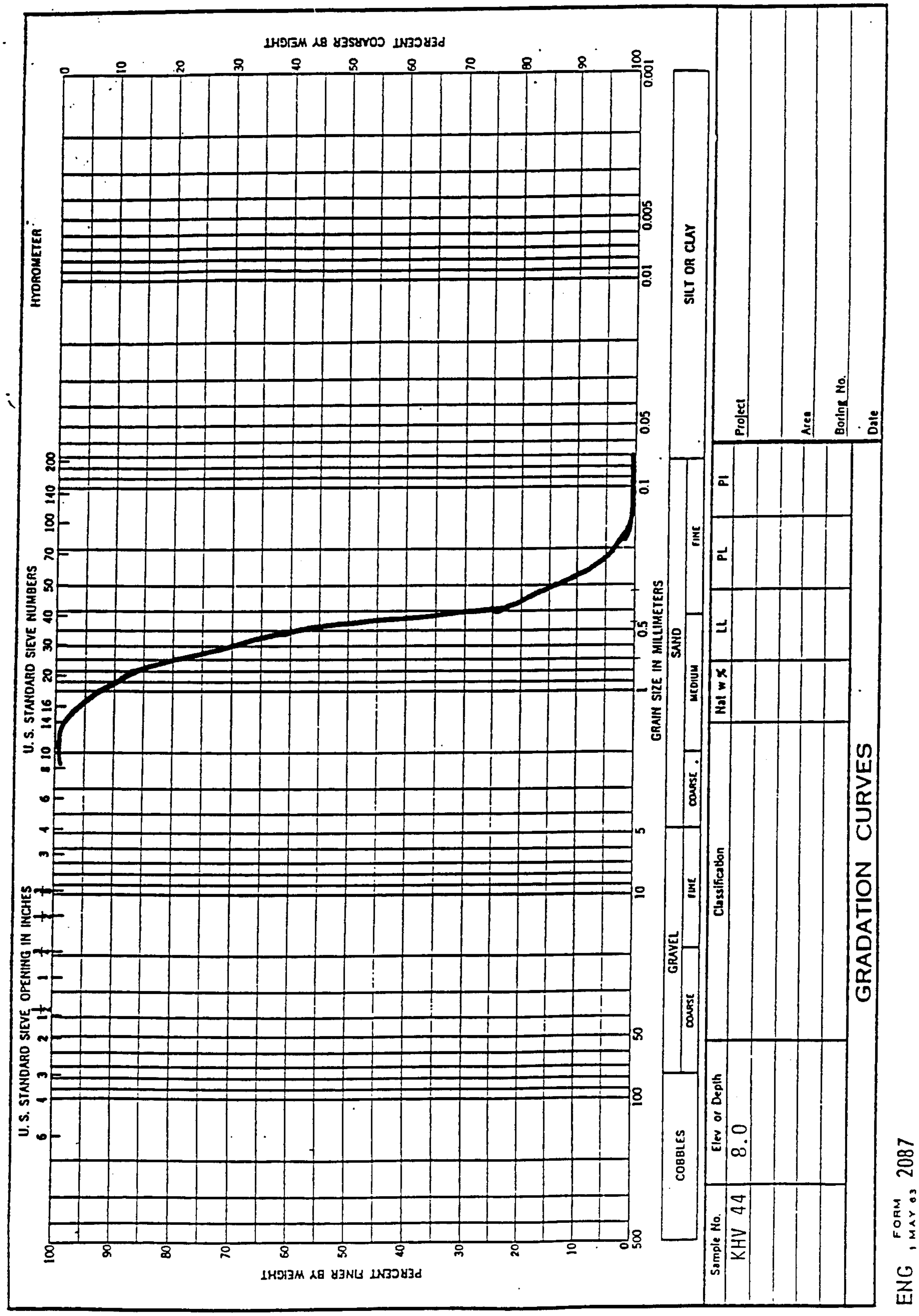
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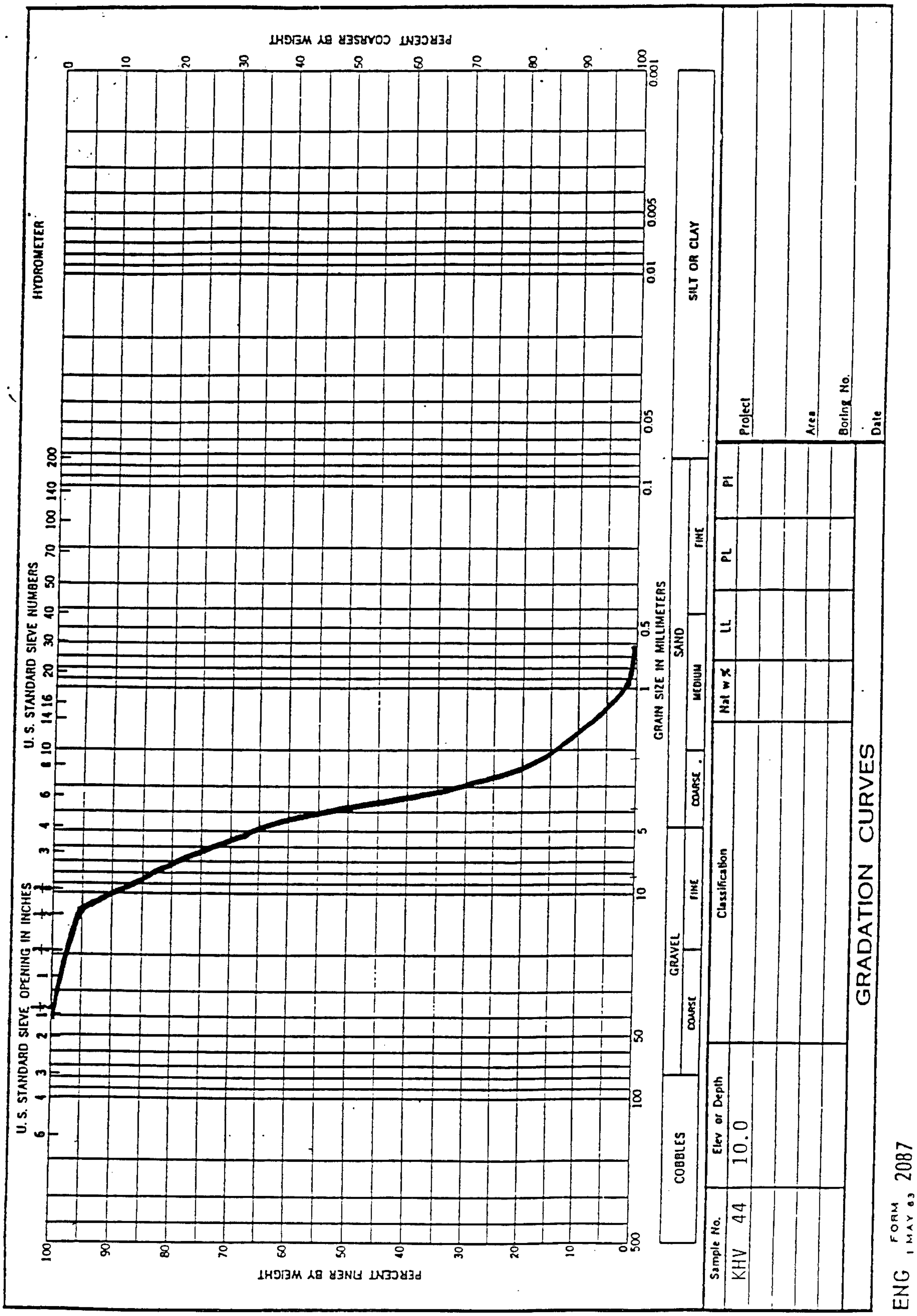
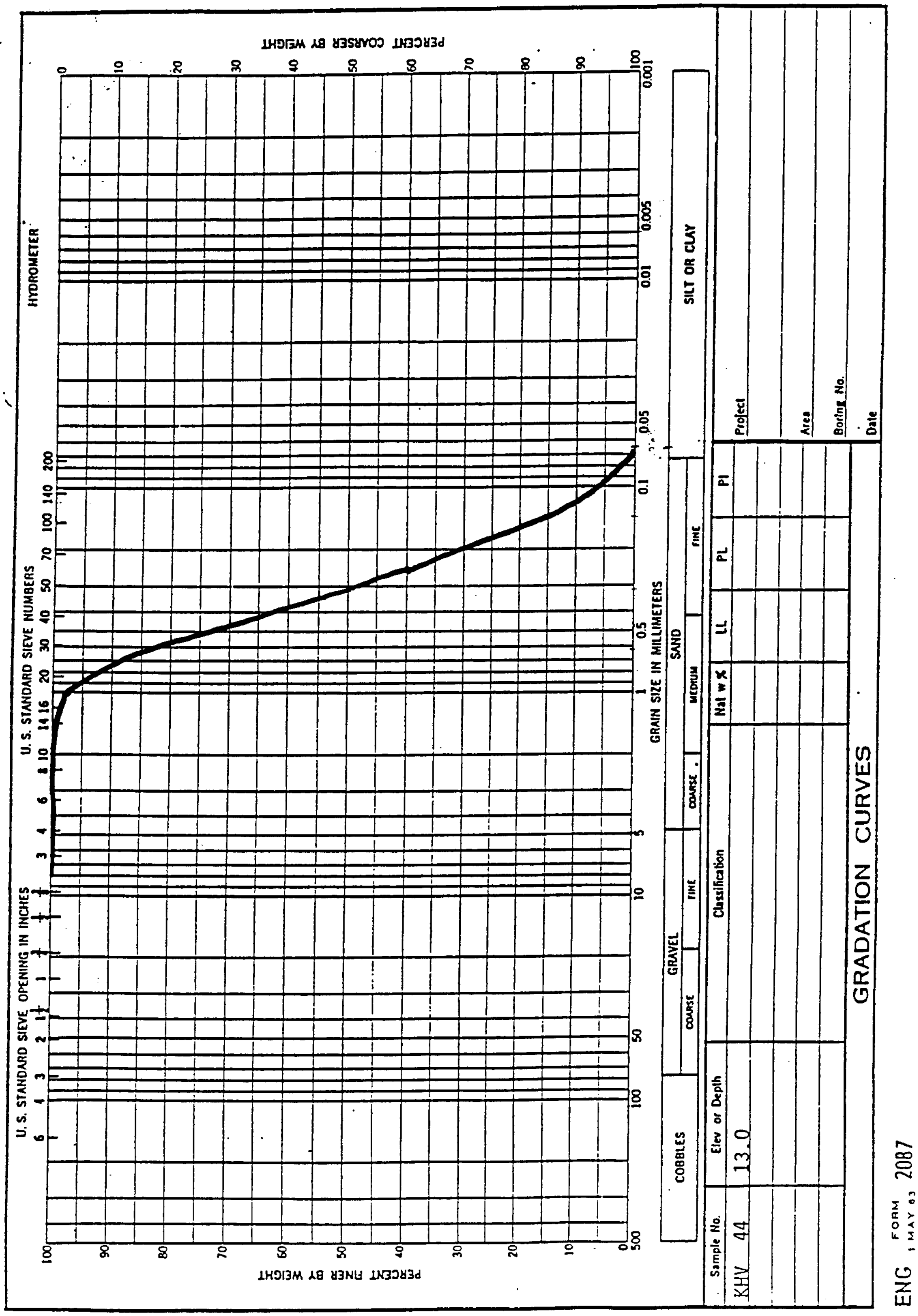
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 44
Elev or Depth
8.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 44
10.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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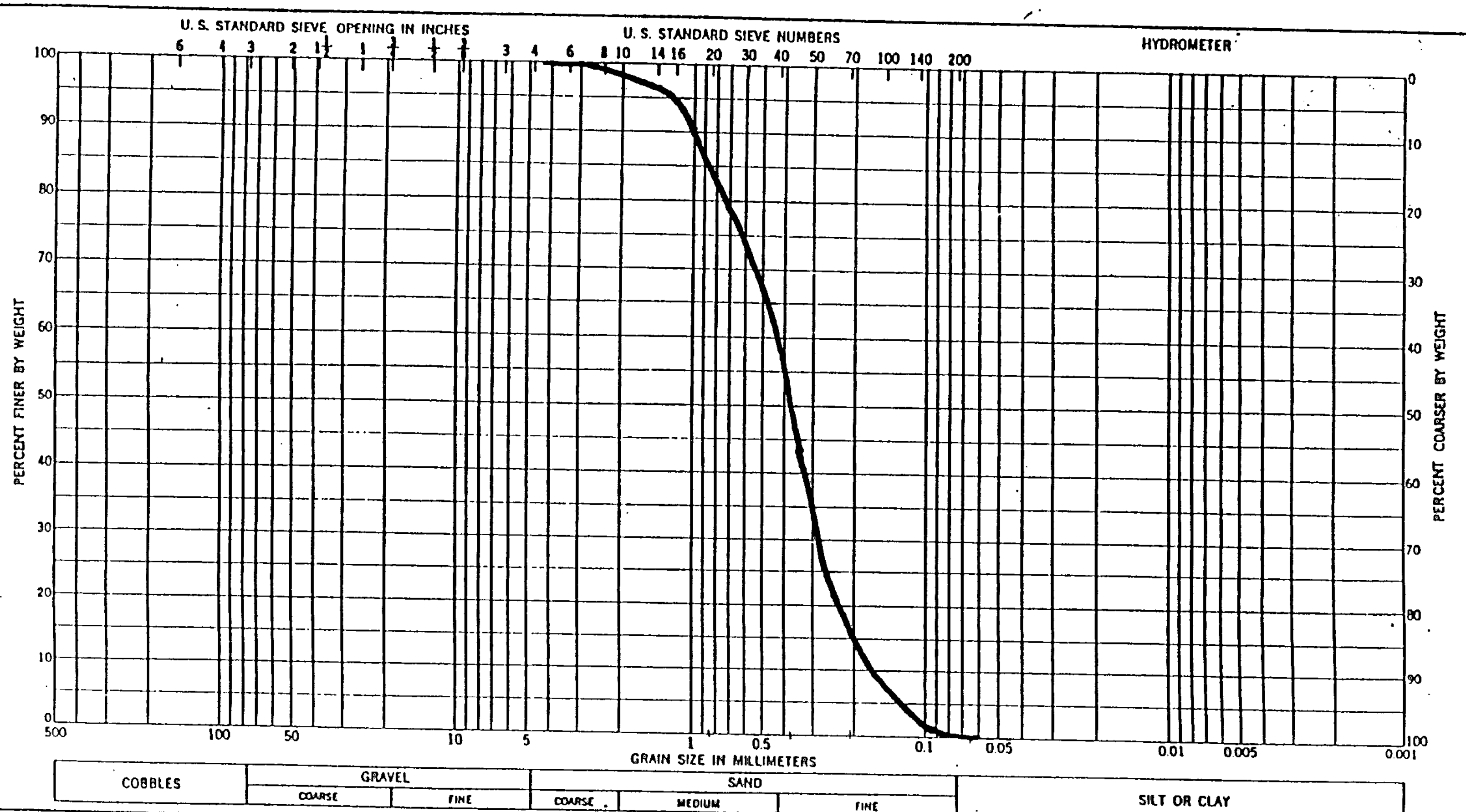
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 44
13.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

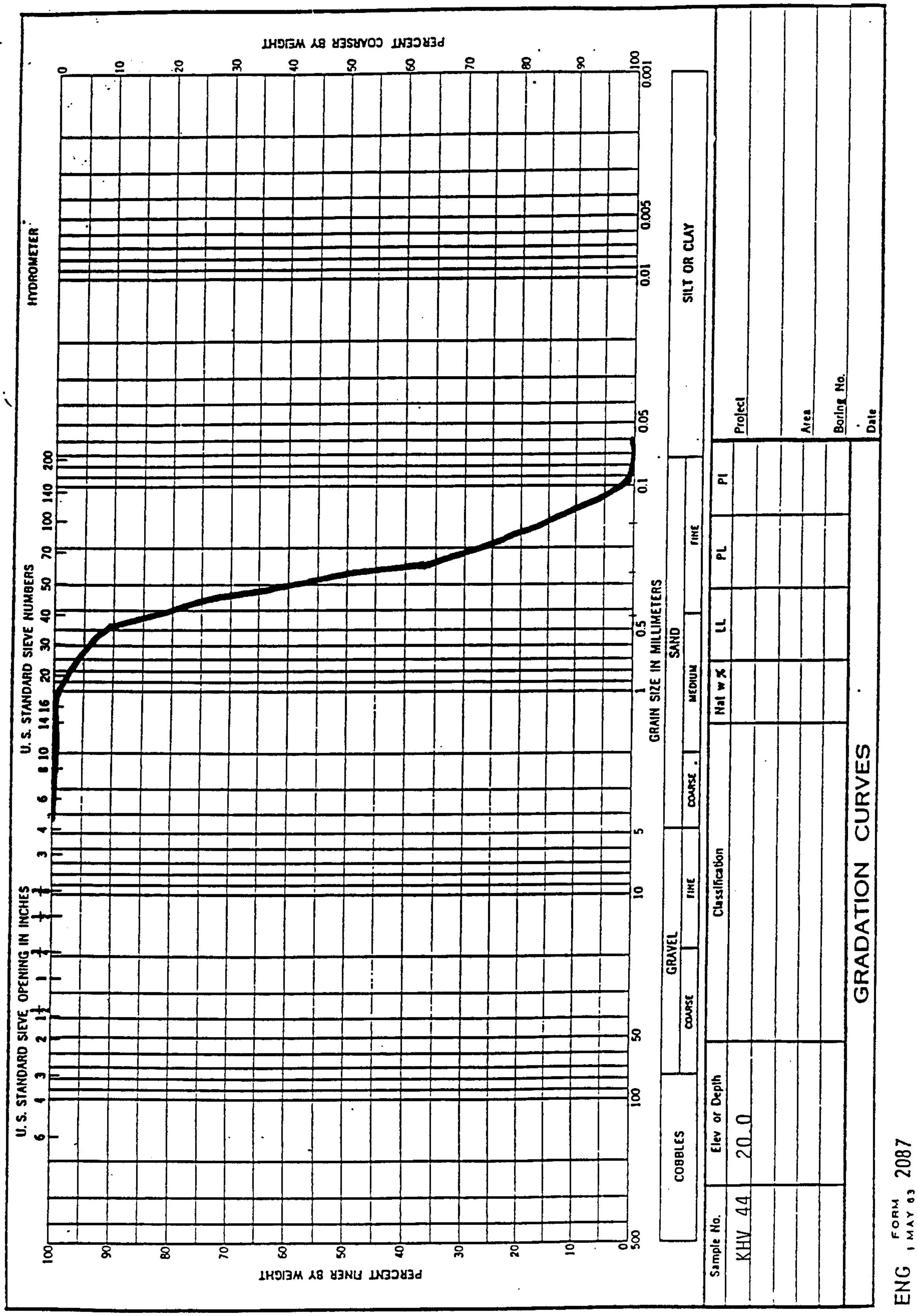


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
KHV 44	17.0					

Project
Area
Boring No.
Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 44
20.0
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	1 of 2 Sheets
2. Location 764876.80E, 171915.80N	10. Size and Type of Bit
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	11. Datum for Elevation Shown (TDM or MSL) MLLW
4. Hole No. (As shown on drawing title) KHV-45	12. Manufacturer's Designation of Drill
5. Name of Driller	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	14. Total No. of Core Boxes
7. Thickness of Overburden	15. Elevation Ground Water
8. Depth Drilled Into Rock	16. Date Hole — Started 6/17/93 — Completed 6/17/93
9. Total Depth of Hole 16.1 ft	17. Elevation Top of Hole -36.2'
	18. Total Core Recovery for Boring %
	19. Signature of Inspector JV

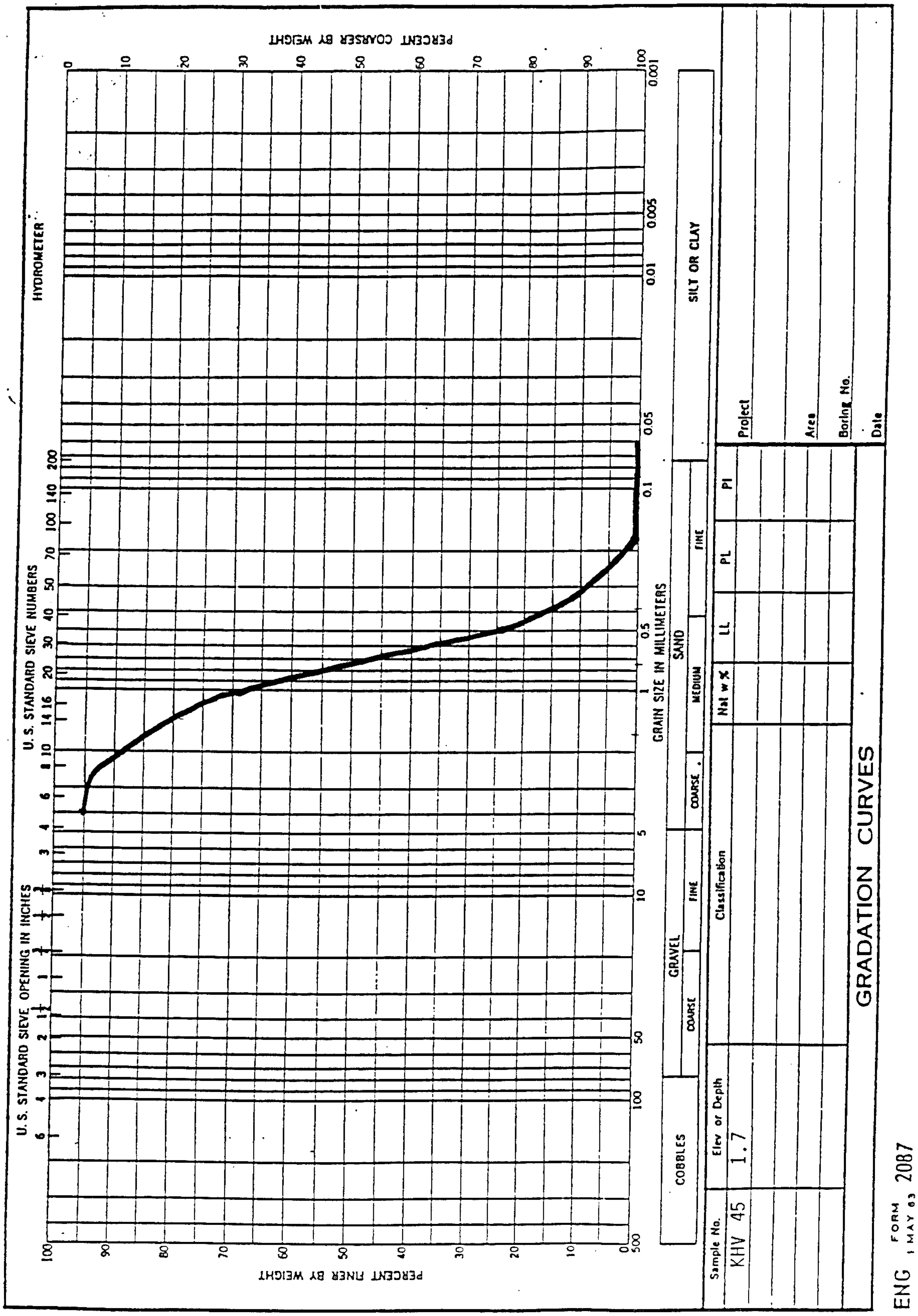
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0	SP	Gray, medium sand; wet			Run 1: 0'–18'; 13.7' recovery Run 2: 13'–16'; 2.4' recovery
	1					
	2					Sample at 1.7'
			Light gray, medium sand			
	3					
	4	SP	Light gray, medium sand; trace of gravel			
	5					
	6					Sample at 6.0'
	7	SP				
	8		Light gray, coarse to medium sand; trace of gravel			
	9					
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -36.2'	Hole No. KHV-45
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Light gray, medium sand			
	11					
	12					
	13	SP	Light gray, medium sand			Sample at 13.0'
	14					End Run 1
		SP	Light gray, medium sand			Run 2 Sample at 14.7'
	15					
	16		16.1 ft End Run 2			
	17					
	18					
	19					
	20					
	21					

NG FORM 1836 Project Hole No.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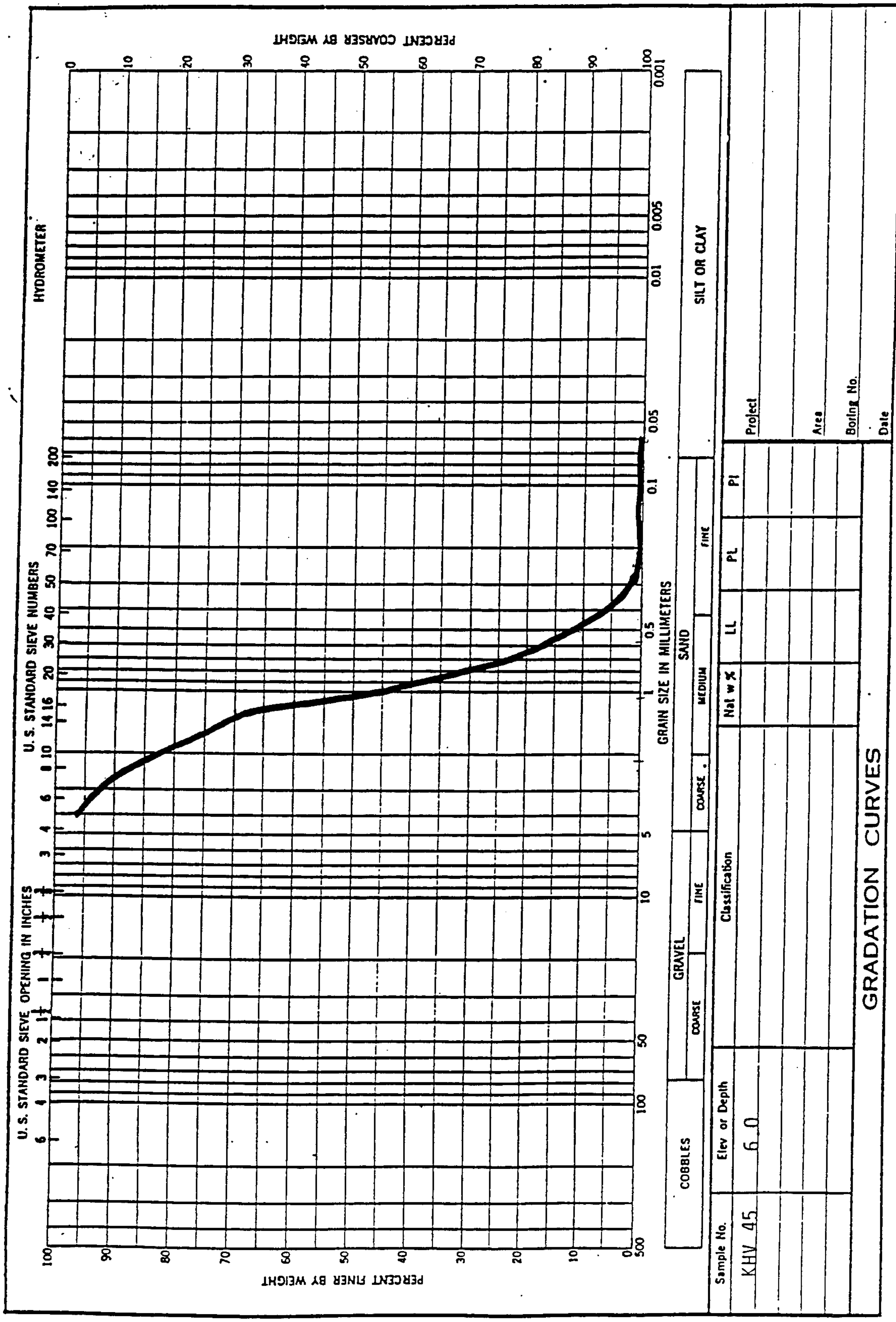
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 45
Elev or Depth
1.7
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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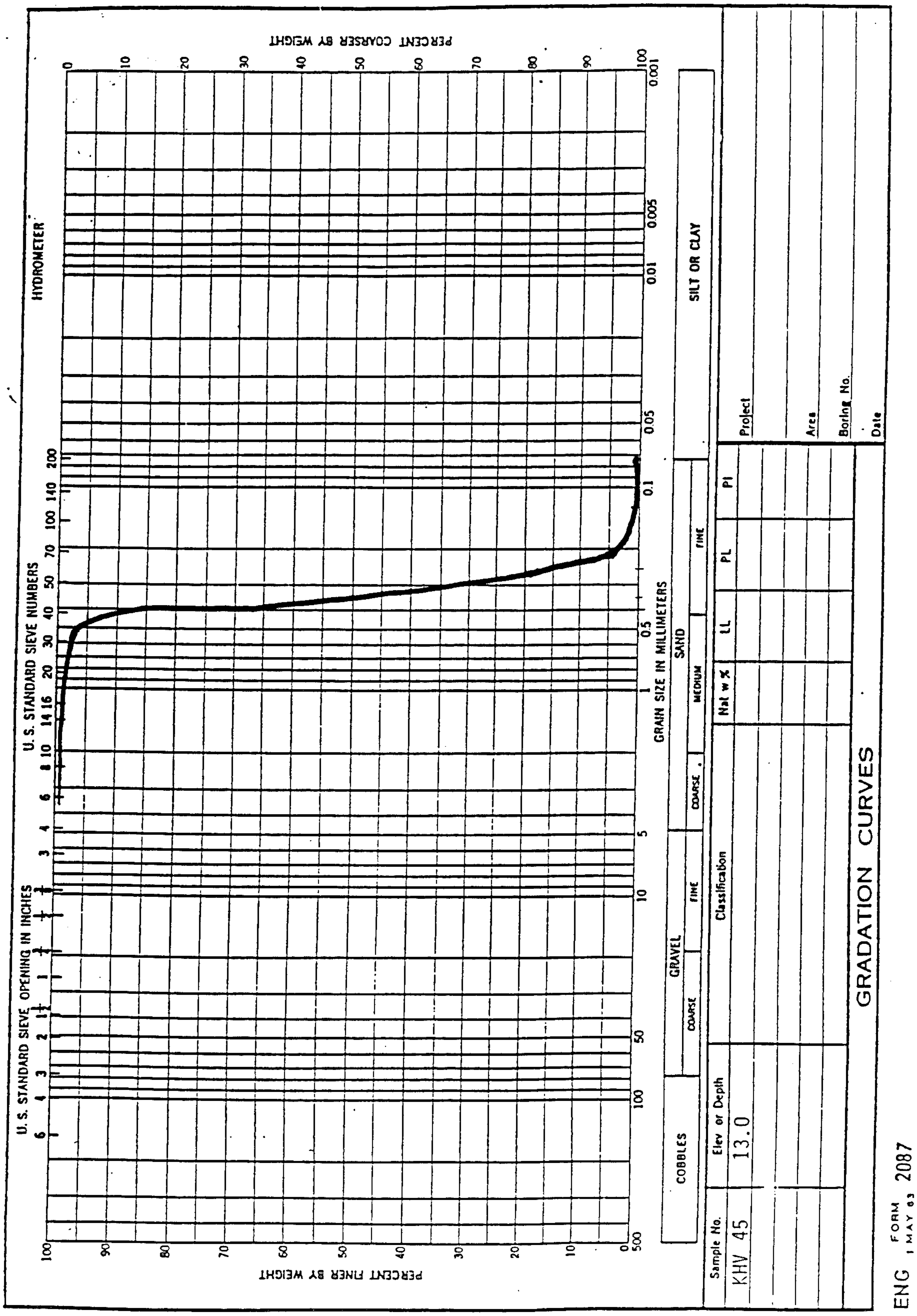
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 45
Elev or Depth
6.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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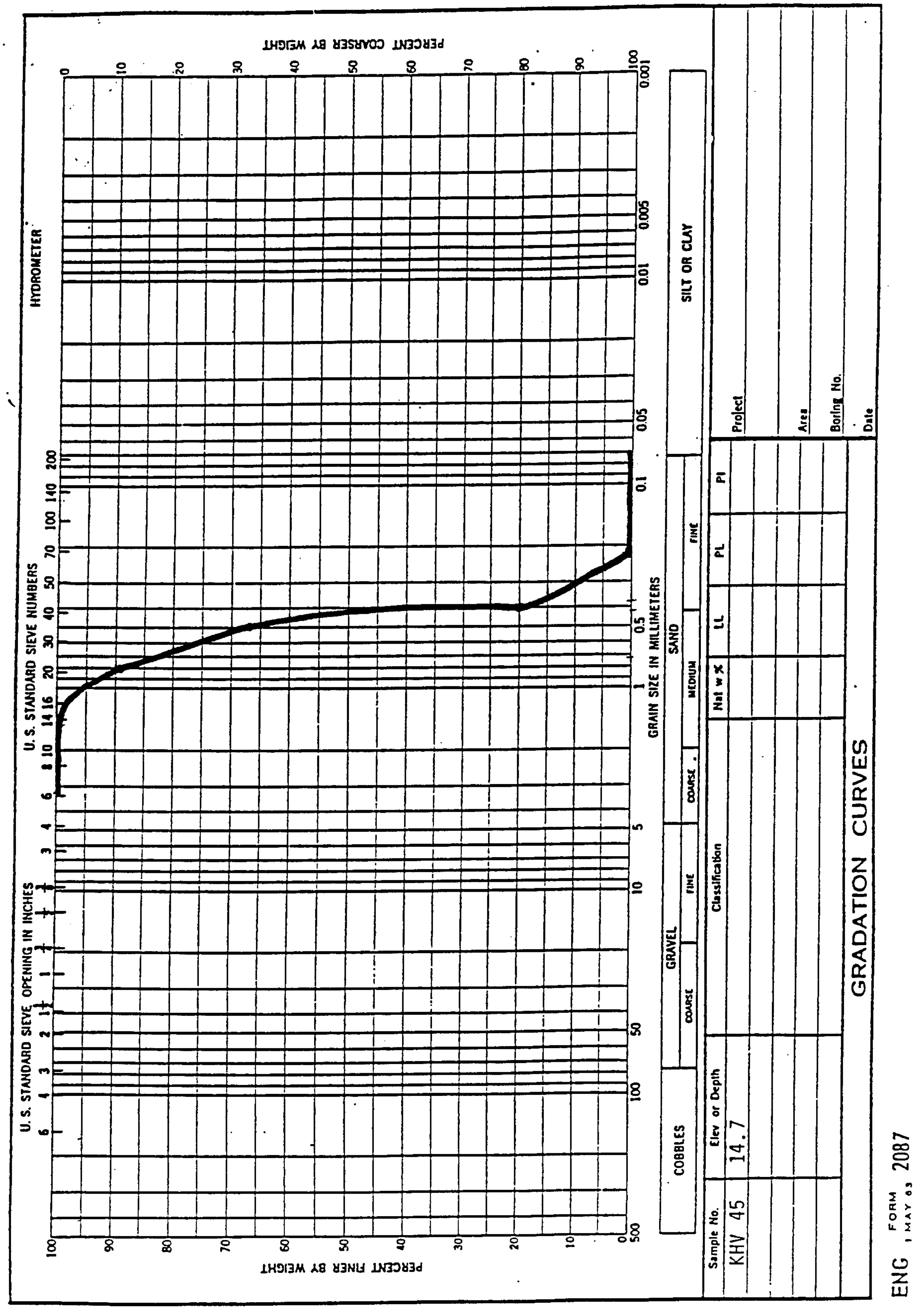
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 45
13.0
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
SAND
SILT OR CLAY
Sample No.
KHV 45
Elev or Depth
14.7
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log | 1 of 2 Sheets

1. Project: KHV
2. Location: 764412.20E, 223234.10N
Drilling Agency: Alpine Ocean Seismic Survey, Inc.
4. Hole No. (As shown on drawing title): KHV-46
5. Name of Driller:
6. Direction of Hole: [x] Vertical [ ] Inclined ______ Degree from Vertical
7. Thickness of Overburden:
8. Depth Drilled Into Rock:
9. Total Depth of Hole: 18.6 ft
10. Size and Type of Bit:
11. Datum for Elevation Shown (TDM or MSL): MLLW
12. Manufacturer's Designation of Drill:
13. Total No. of Overburden Samples Taken: Disturbed | Undisturbed
14. Total No. of Core Boxes:
15. Elevation Ground Water:
16. Date Hole: Started 6/10/93 | Completed 6/10/93
17. Elevation Top of Hole: -40.7'
18. Total Core Recovery for Boring: %
19. Signature of Inspector: JV GZ

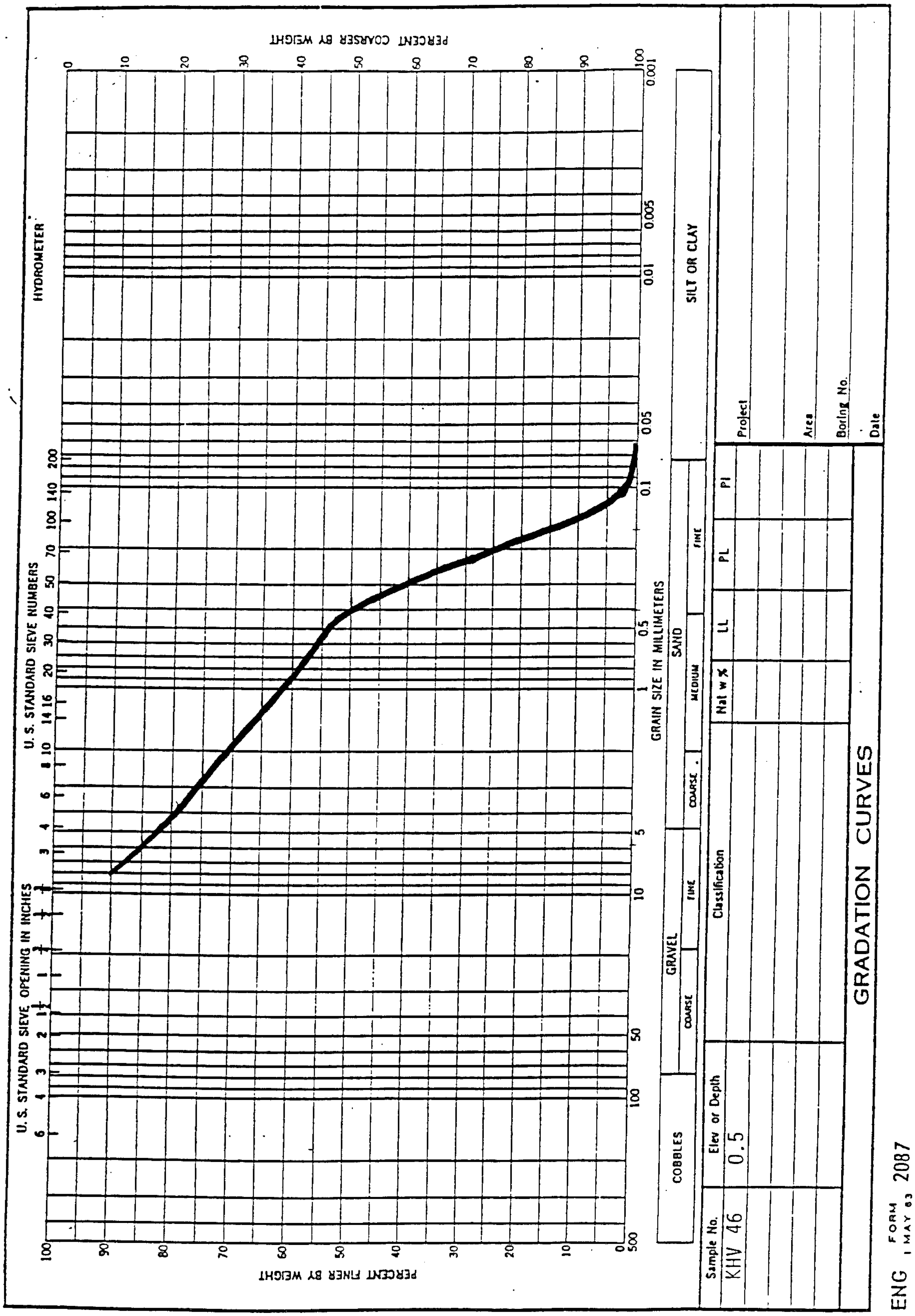
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0	SP	Dark gray, muddy sand and gravel	100		Sample at 0.5'
	2	CL	Dark gray, silty clay			Sample at 1.8'
	3	SP	Dark gray, muddy sand	100		
	5	SP	Dark gray, muddy sand			Sample at 5.2'
	7	SP	Dark gray, muddy fine sand			Sample at 8.2'
	9	OL	Dark gray, silty clay	100		Sample at 9.0'
	10					

ENG FORM 1836 | Project | Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -40.7'	Hole No. KHV-46
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	OL	Dark gray, silty clay	100		Sample at 11.6'
	13	SM	Gray, muddy sand			
	14	OL	Dark gray, silty clay			
	15	SM	Gray, muddy, fine sand; trace of gravel			Sample at 15.2'
	17	SM	Light gray, muddy, fine sand			
	18	SW	Coarse sand; well graded 18.6 ft Recovery	100		Sample at 18.2'
	19					
	20					
	21					

ENG FORM 1836 Project Hole No.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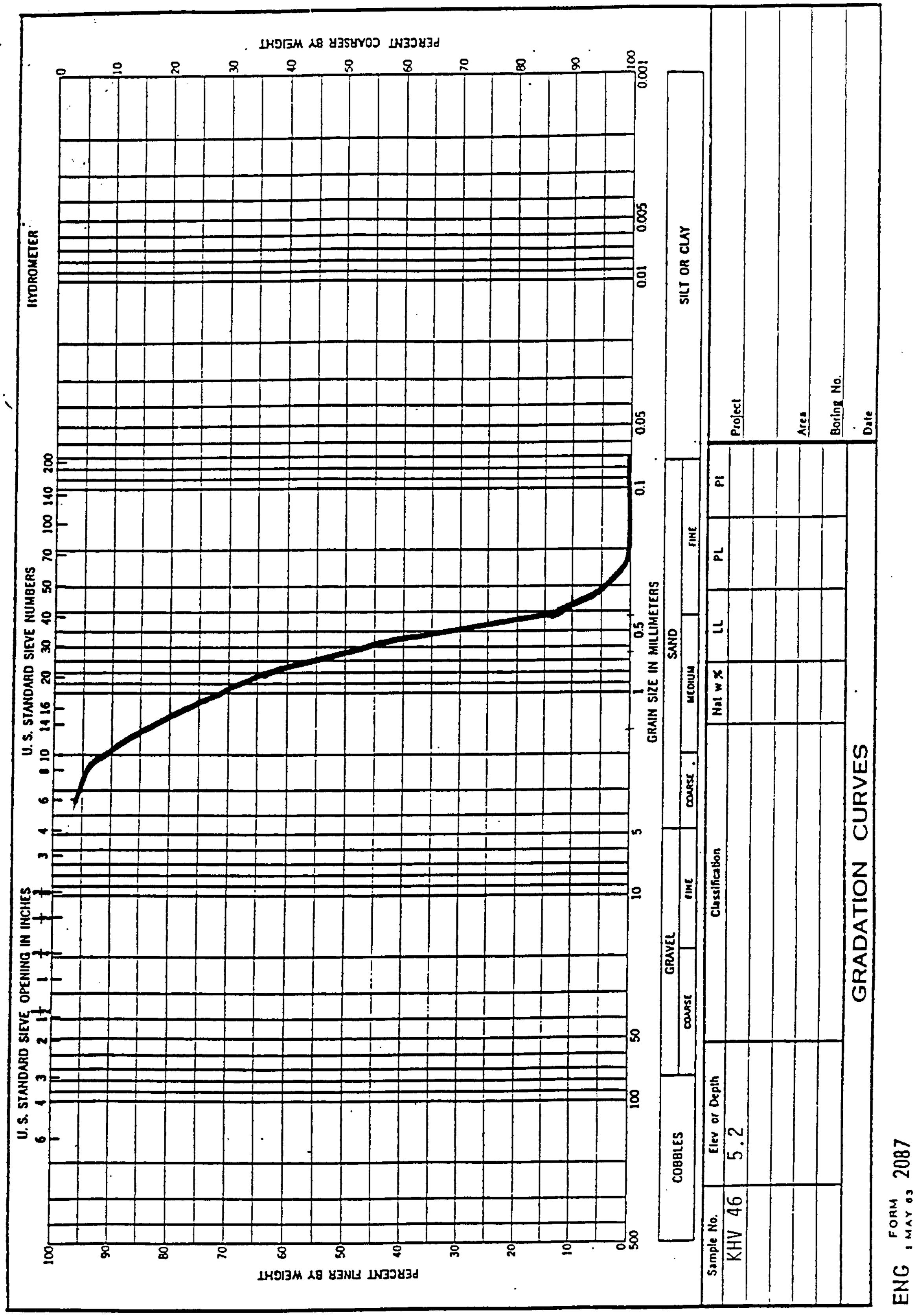
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 46
Elev or Depth
0.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
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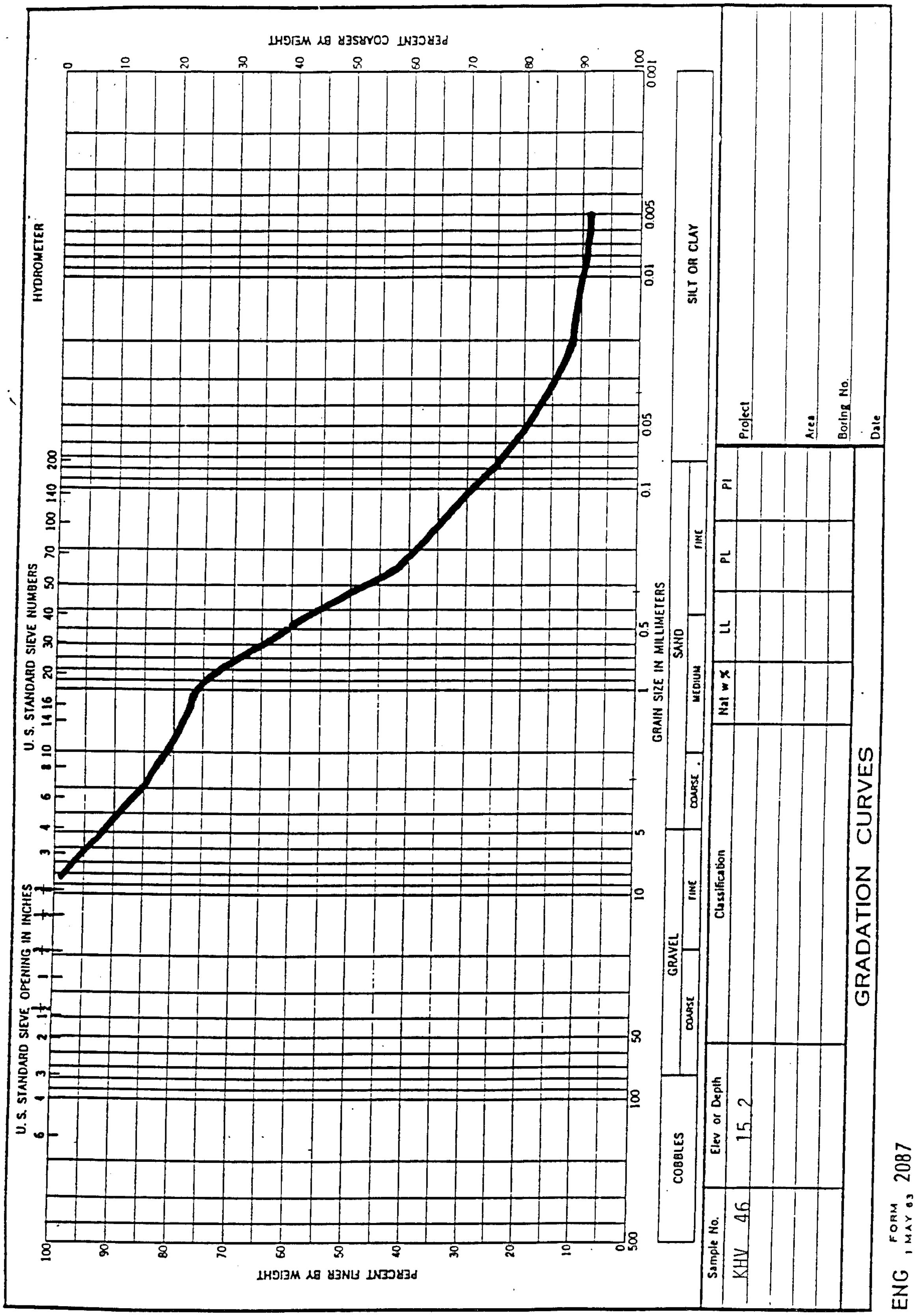
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 46
Elev or Depth
5.2
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 46
Elev or Depth
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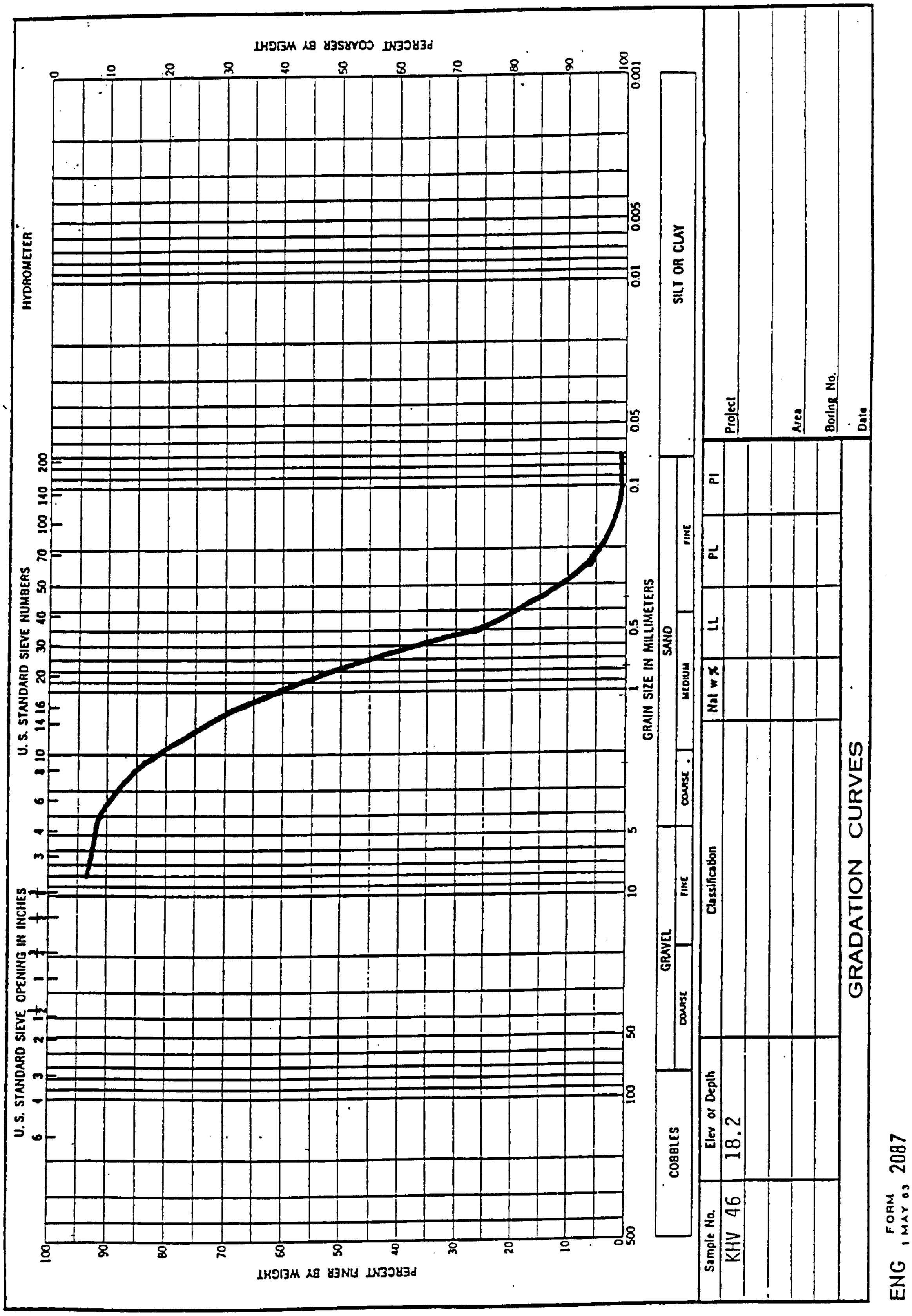
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 46
18.2
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

1. Project: KHV	10. Size and Type of Bit
2. Location: 765794.30E, 188621.00N	11. Datum for Elevation Shown (TDM or MSL): MLLW
3. Drilling Agency: Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title): KHV-47	13. Total No. of Overburden Samples Taken — Disturbed: — Undisturbed:
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole: [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started: 6/13/93 — Completed: 6/13/93
	17. Elevation Top of Hole: -41.2'
7. Thickness of Overburden	18. Total Core Recovery for Boring: %
8. Depth Drilled Into Rock	19. Signature of Inspector: JV
9. Total Depth of Hole: 18 ft	

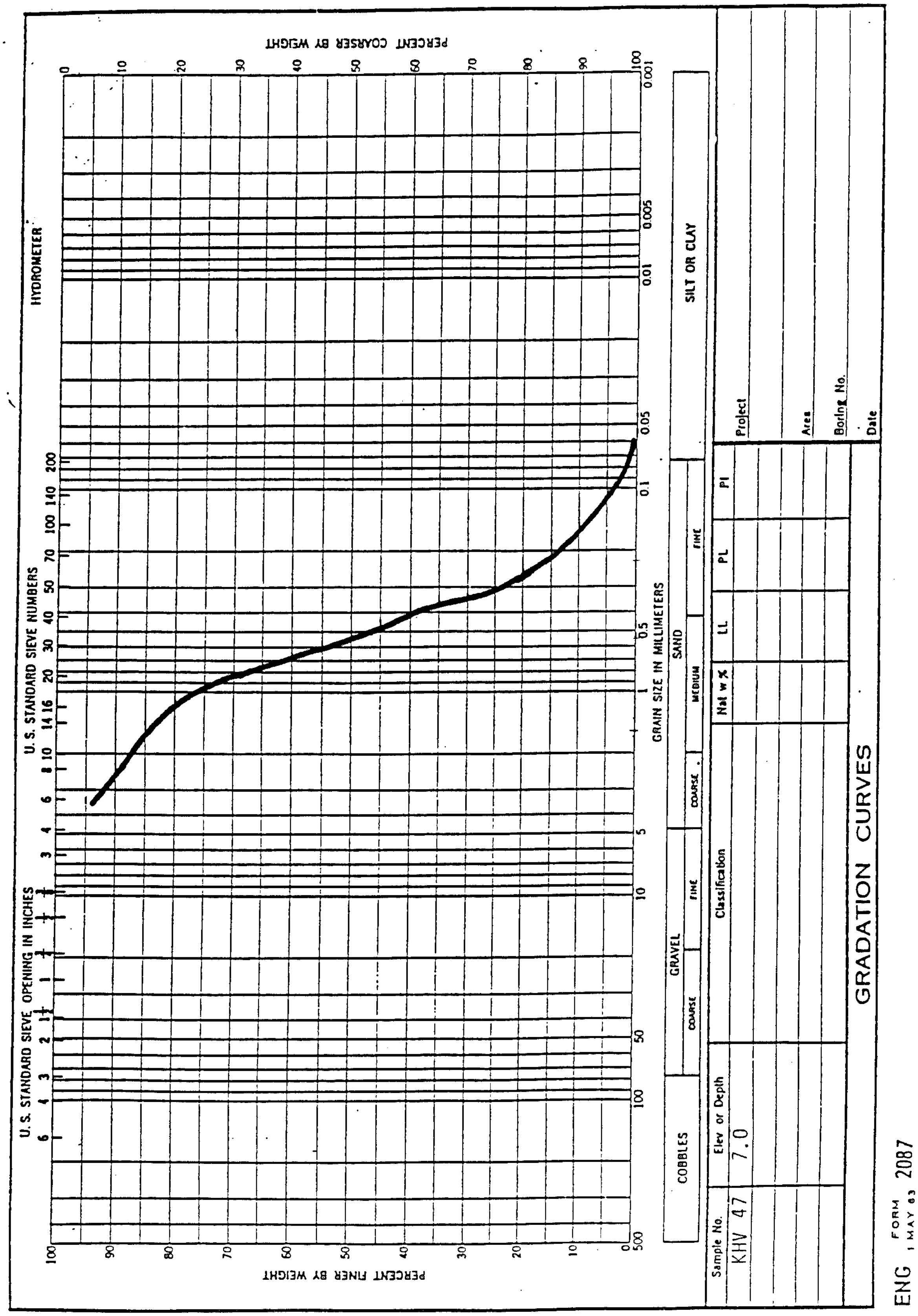
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0–3	CH	Gray brown clay; very moist, very plastic	100		Run 1: 0'–11.6' H_2S smell Moisture content seems to drop greatly at clay–silt interface
	3–5	OL	Greenish silt and some fine sand streaked with Fe oxide			
	5–6.6	SW	Tan to gray, coarse sand; trace of silt; some medium sand	100		
	6.6–9.5	SW	Tan to gray, coarse sand; stained with Fe oxide at 7'; trace of rounded gravel; lenses of green clay at ~9'	100		Sample at 7.0' Lens of brown clay at 7' Begin Run 2
	9.5–10	SP	Gray, medium sand			

ENG FORM 1836 | Project | Hole No.

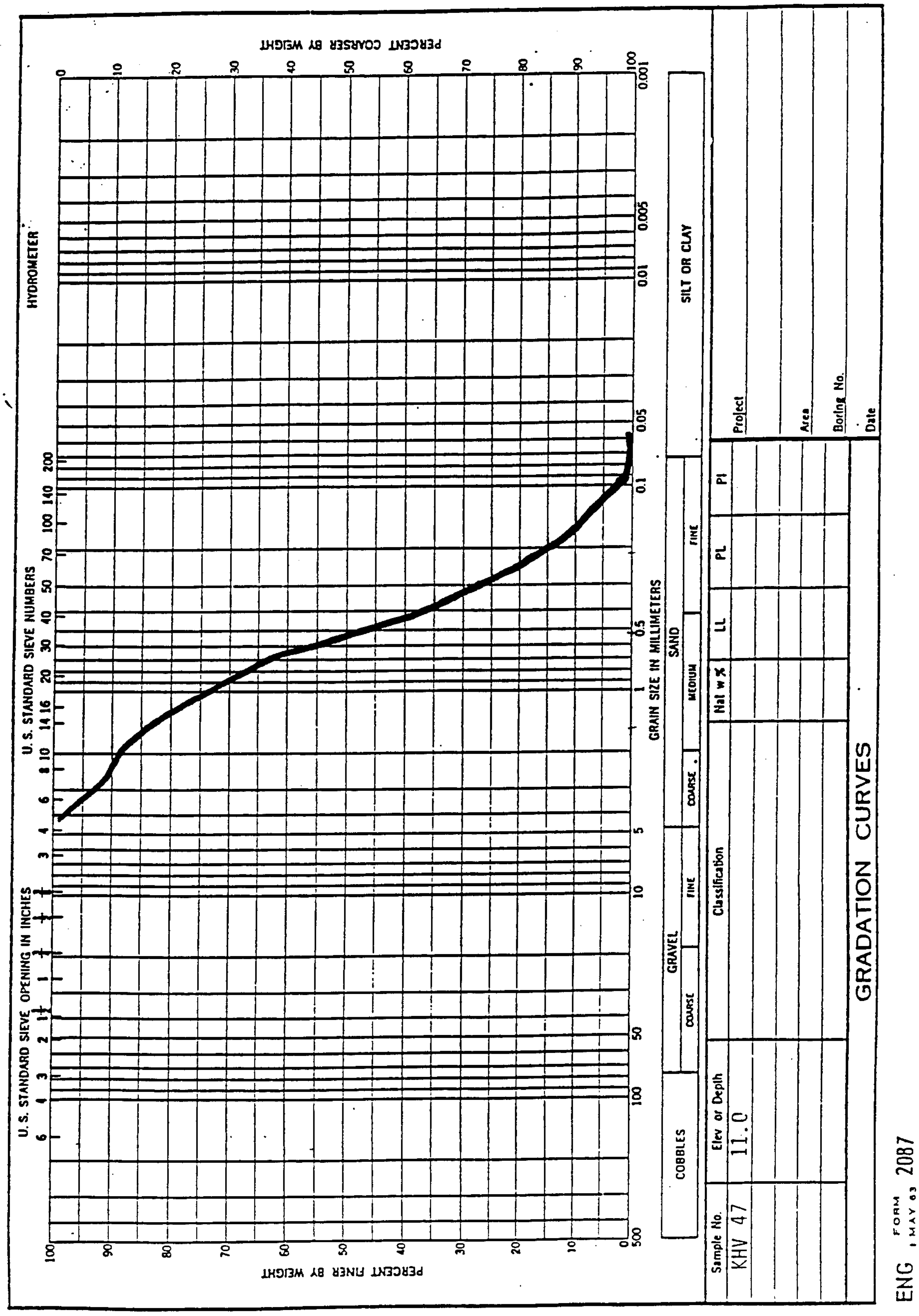
Drilling Log (Cont Sheet)	Elevation Top of Hole -41.2'	Hole No. KHV-47
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray bown, medium sand; occasional lens of geen clay	100		
	11					Sample at 11.0' End Run 1
	12	ML	Light brown, silty clay			
	13	SP	Light gray, medium sand; trace of silt			
	14					Sample at 14.0'
	15					
	16	SP	Light gray, medium sand	100		
	17					Sample at 17.5'
	18		18 ft Recovery			
	19					
	20					
	21					

NG FORM 1836 Project Hole No.



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
MEDIUM
SILT OR CLAY
Sample No.
KHV 47
Elev or Depth
7.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
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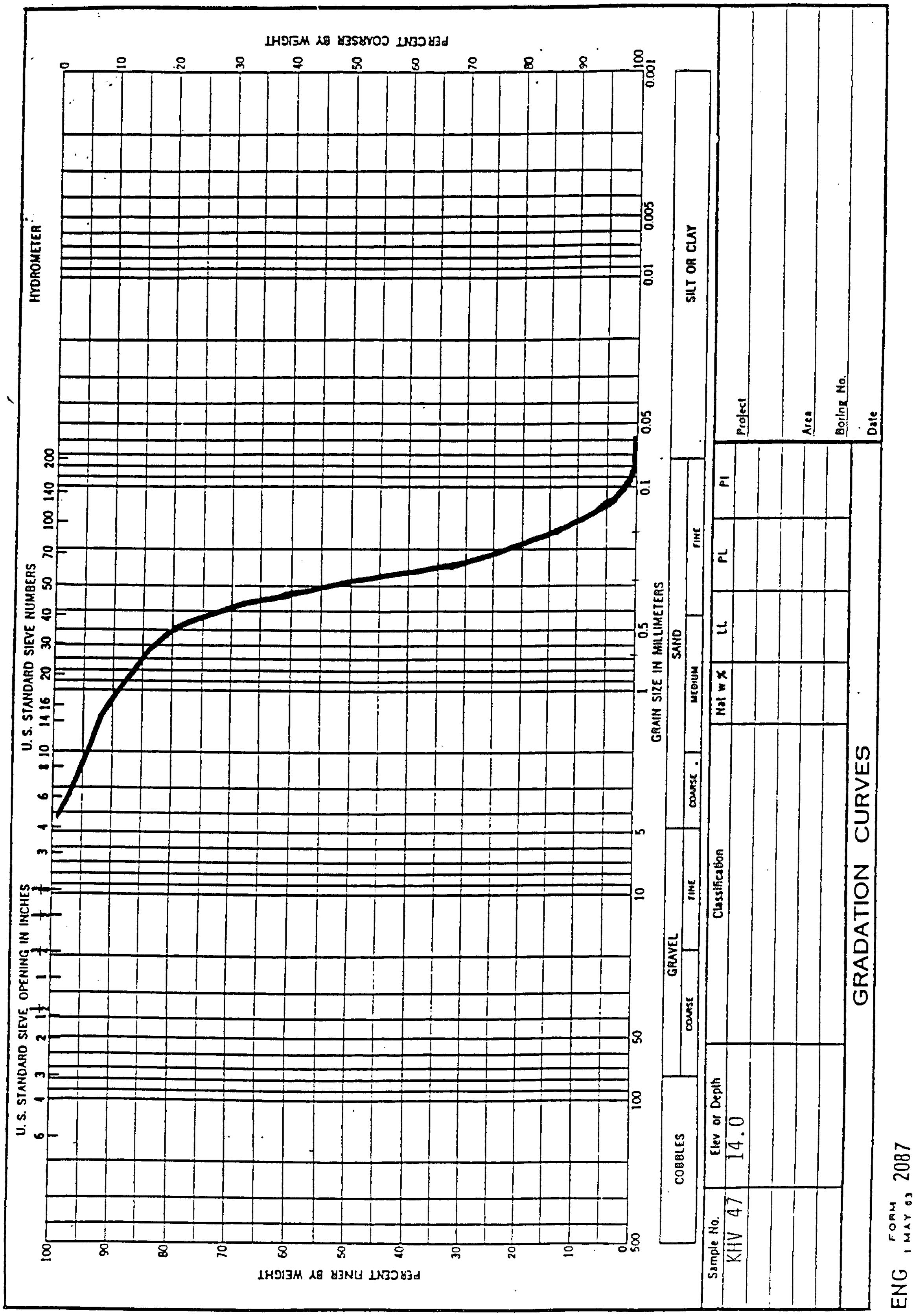
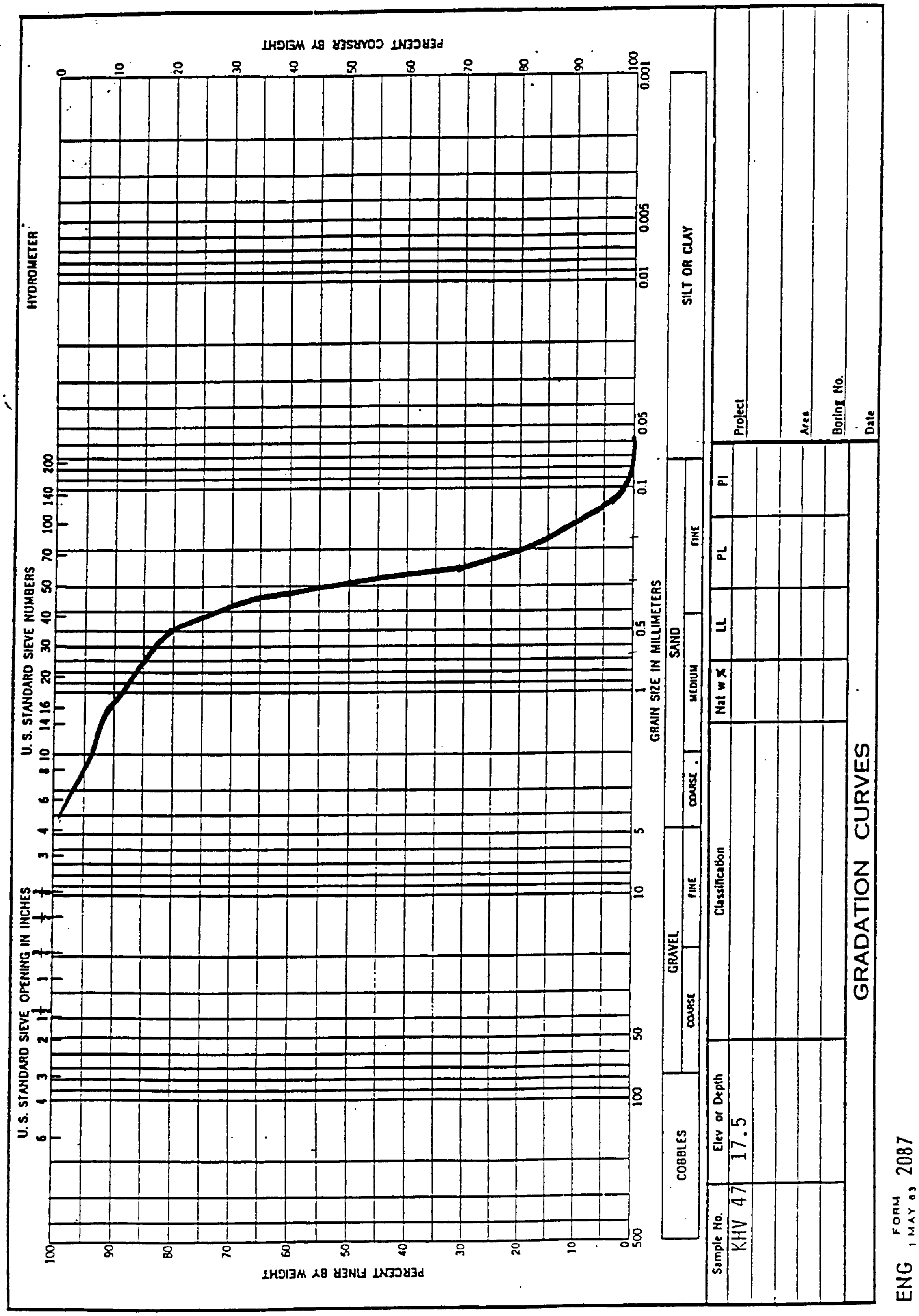
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 47
Elev or Depth
11.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 47
Elev or Depth
14.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 47
Elev or Depth
17.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	1 of 2 Sheets
	10. Size and Type of Bit
2. Location 769852.60E, 171381.20N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-48	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/17/93 — Completed 6/17/93
7. Thickness of Overburden	17. Elevation Top of Hole -34.3'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 19.5 ft	19. Signature of Inspector JV GZ

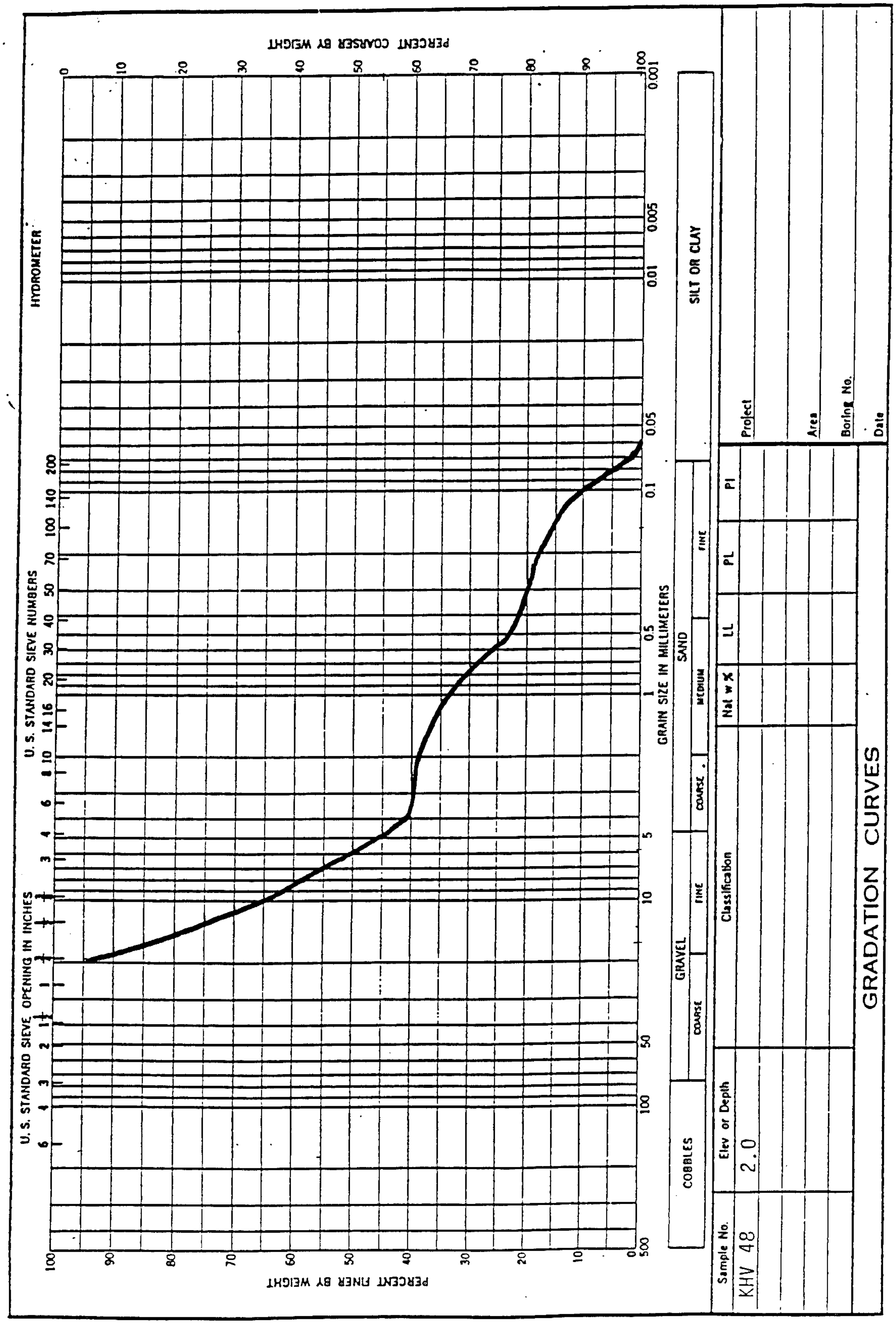
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–1	GW	Brown sand and rounded gravel; clay present increasingly with depth			
	1–4.5		Dark brown, fine sand and clay; trace of rounded gravel			Sample at 2.0'
	4.5–5.8	SP	Brown, fine sand; laminations of brown clay, trace of rounded gravel			Sample at 5.0'
	5.8–7.7	SW	Brown, coarse to fine sand; laminations of clay, trace of rounded gravel			
	7.7–9	SW	Brown, very coarse to fine sand; trace, rounded gravel			Sample at 8.0'
	9–10	SW	Light gray, silty, coarse sand			

ENG FORM 1836 — Project — Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -34.3'	Hole No. KHV-48
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SW	8.9'–19.5' Light gray to tan, medium to coarse sand; lenses of coarse quartz sand at 11.0'–11.5', 12.0'–12.5'; trace of rounded gravel			Sample at 10.0'
	11					Traces of a dark mineral
	12					
	13					Sample at 15.0'
	14					
	15					
	16					
	17					
	18					
	19		19.5 ft Recovery			
	20					
	21					

ENG FORM 1836 Project Hole No.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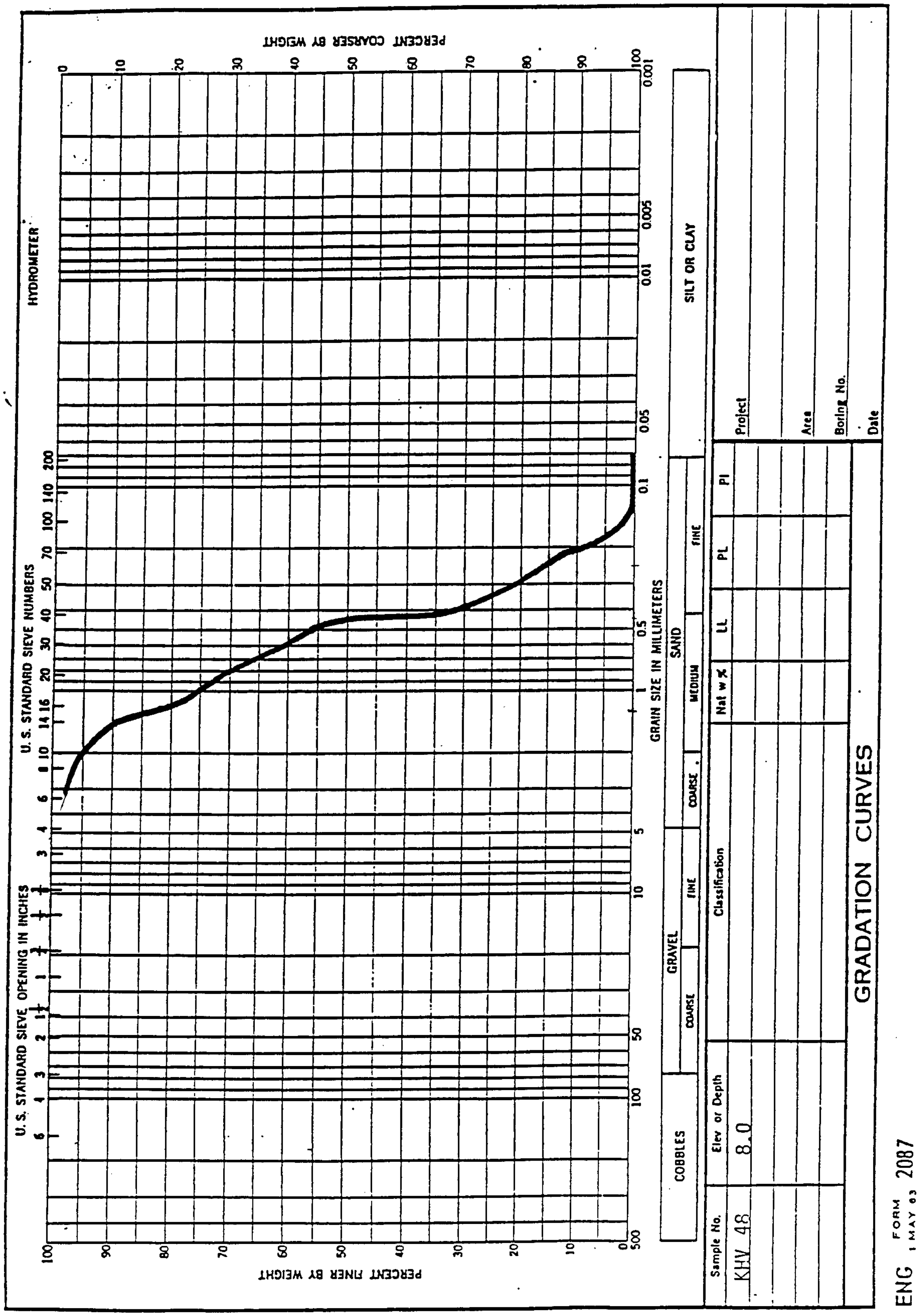
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 48
Elev or Depth
2.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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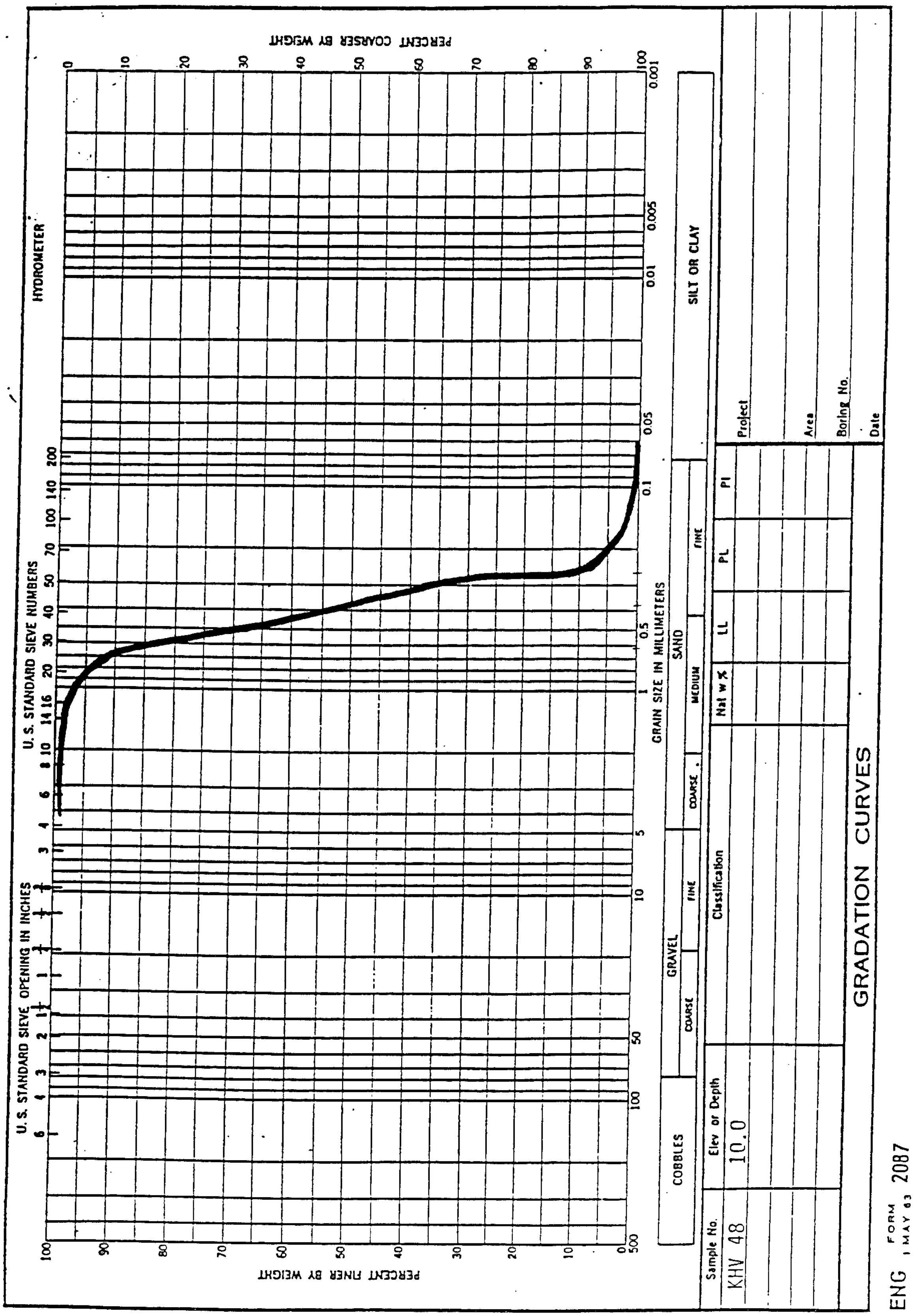
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 48
Elev or Depth
8.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 48
Elev or Depth
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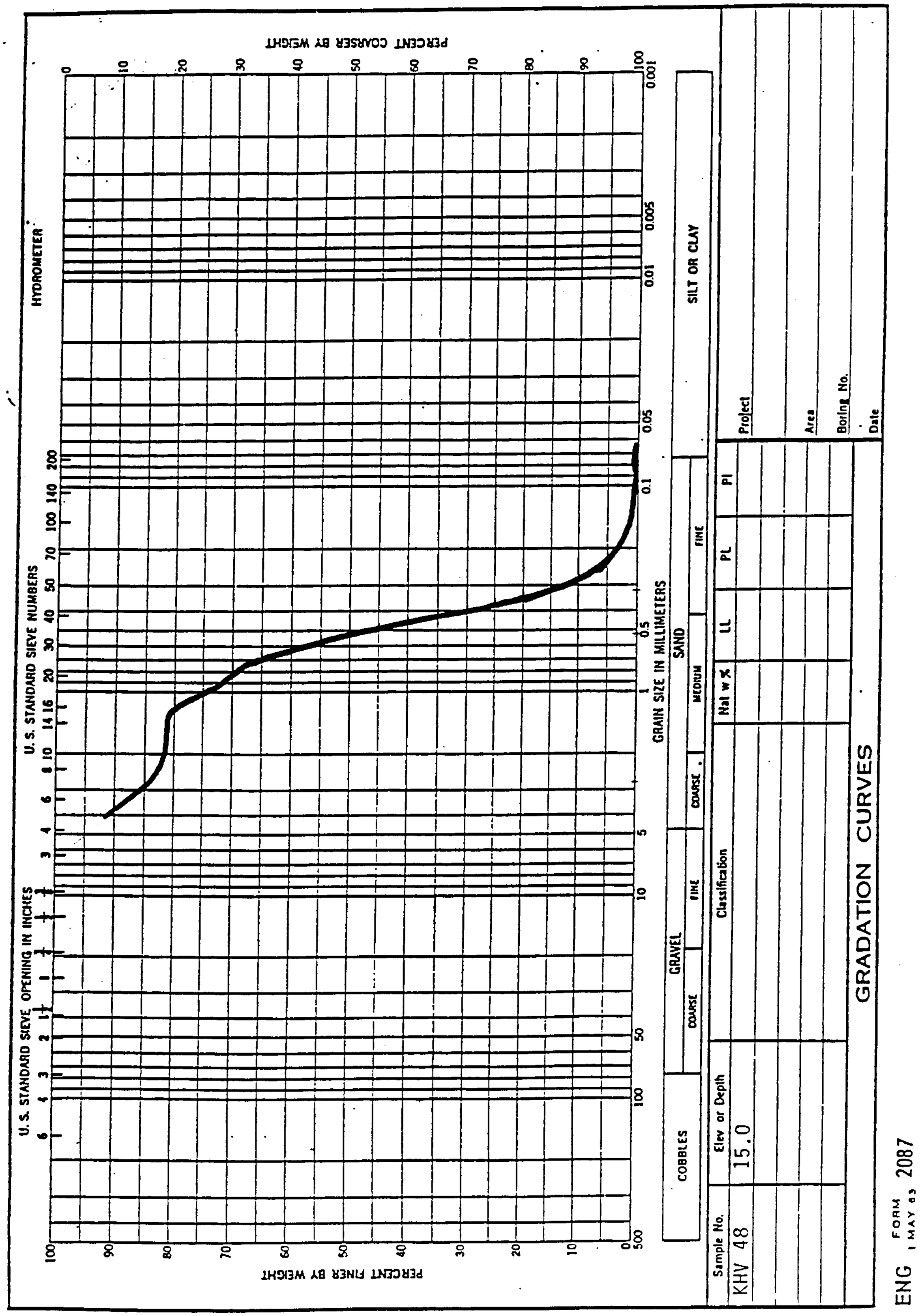
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 48
Elev or Depth
15.0
Classification
Nat w%
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log | | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 770079.60E, 204167.30N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-49	13. Total No. of Overburden Samples Taken — Disturbed: — Undisturbed:
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/10/93 — Completed 6/10/93
7. Thickness of Overburden	17. Elevation Top of Hole -35.7
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 19.5 ft	19. Signature of Inspector JV GZ

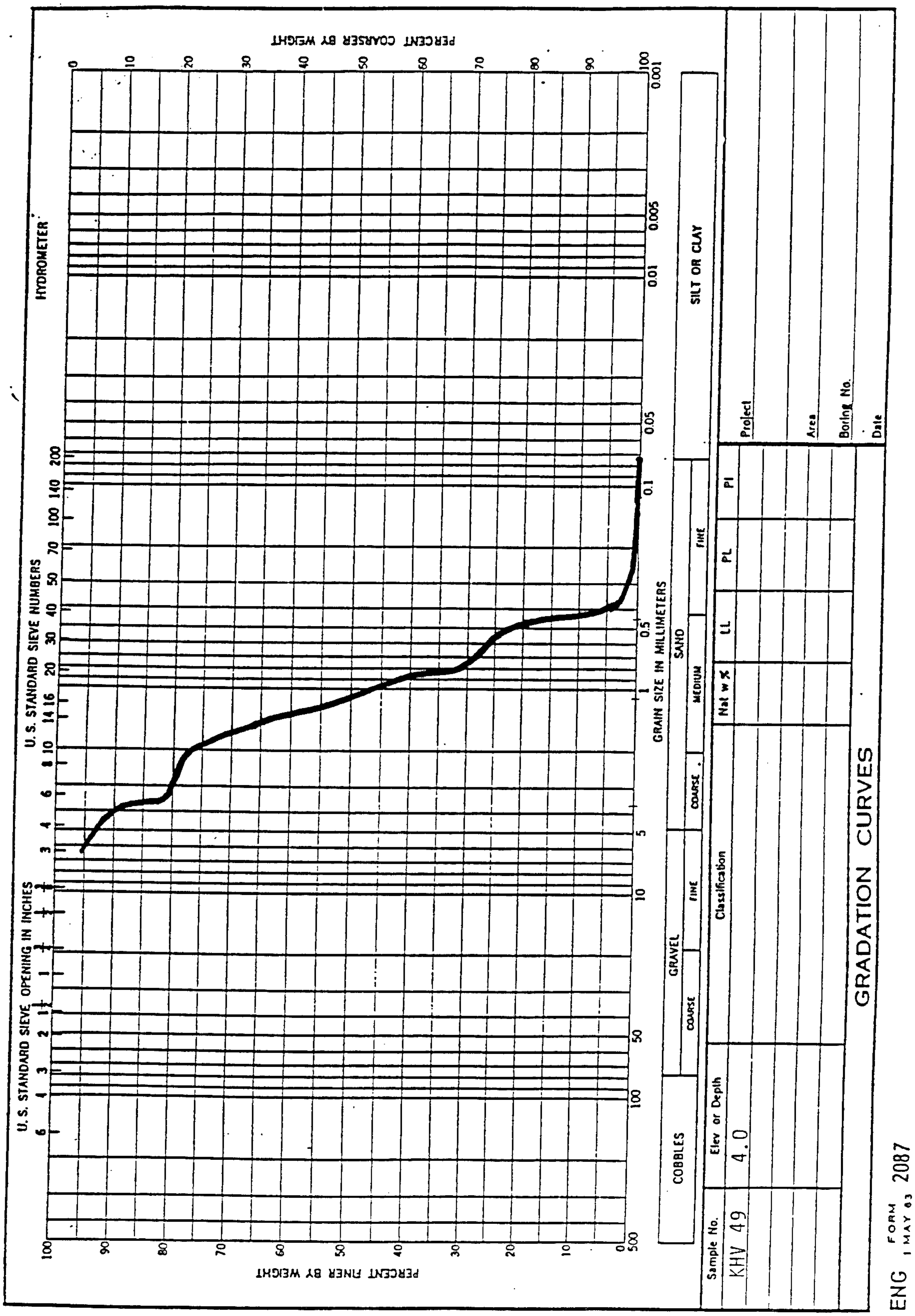
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0–6	SW	Brown, medium to coarse sand; trace of gravel	100		Sample at 4.0'
	6–8.5	SW	Gray-brown sand, as above	100		
	8.5–10	SP	Gray-brown, medium sand			Sample at 9.0'

ENG FORM 1836 | Project | Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -35.7'	Hole No. KHV-49
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray, silty, medium to coarse sand			
	11 12	SW	Gray, coarse sand and gravel; large and rounded			Sample at 11.0'
	13 14	SW	Gray, very coarse sand and gravel; clean			Sample at 14.2'
	15	GW	Medium gray sand, wet; and coarse round gravel			
	16	SP	Medium gray sand			Sample at 16.2'
	17 18	SW	Very coarse, rounded sand and grave; wet			Sample at 17.7'
	19	SW	Gray, coarse sand and coarse gravel, wet 19.5 ft Recovery			Sample at 19.0'
	20 21					

NG FORM 1836 Project Hole No.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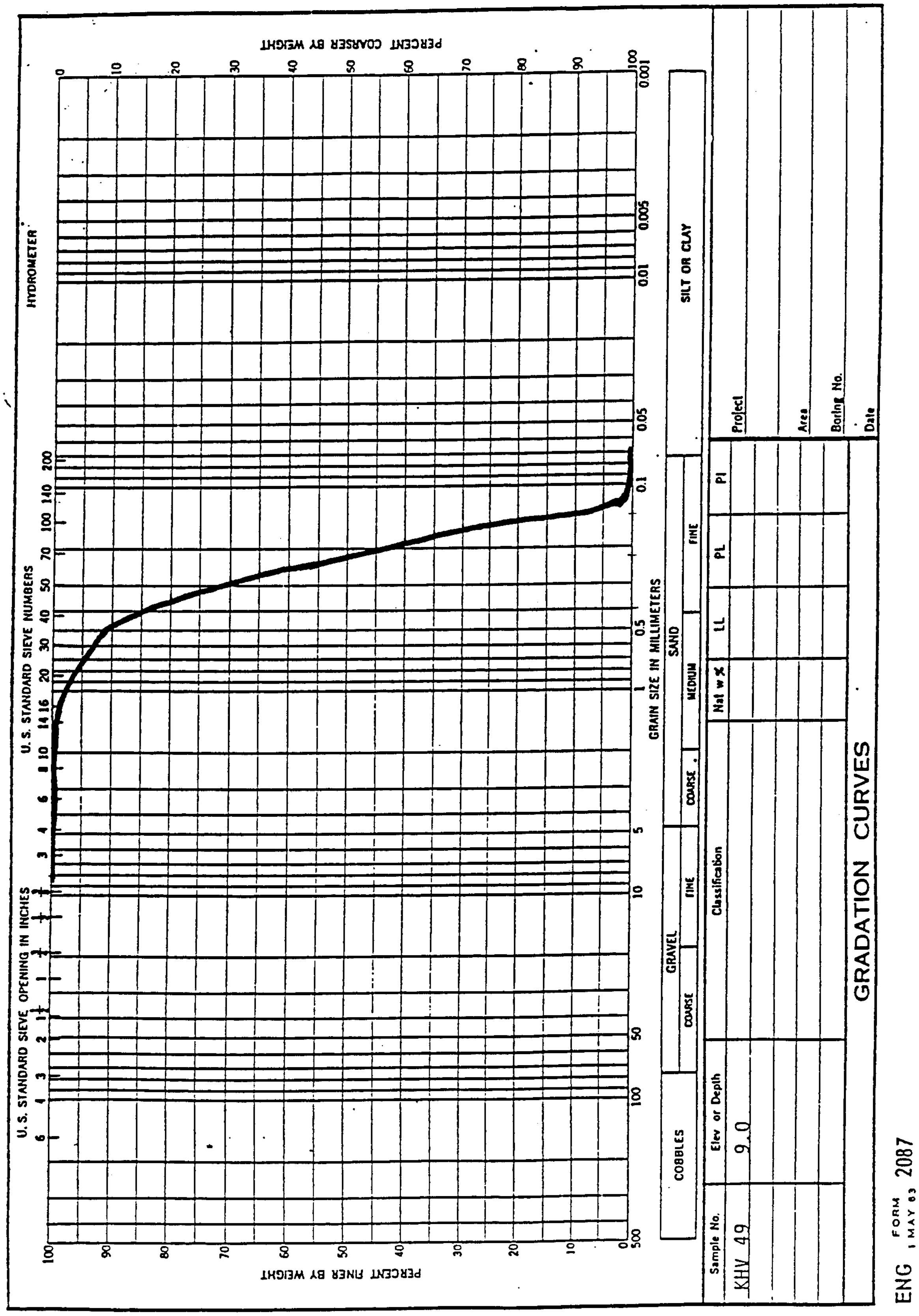
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 49
Elev or Depth
4.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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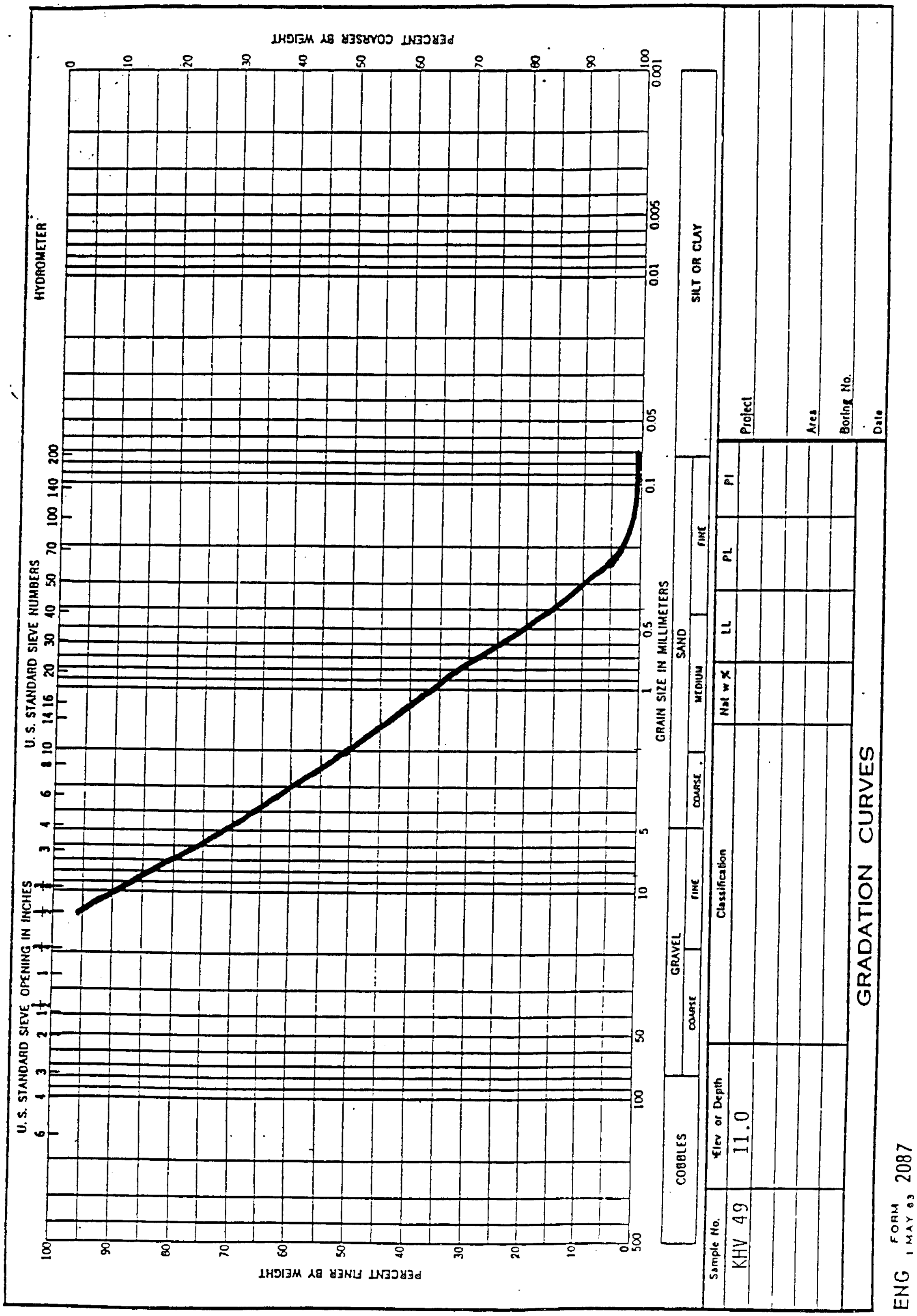
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 49
Elev or Depth
9.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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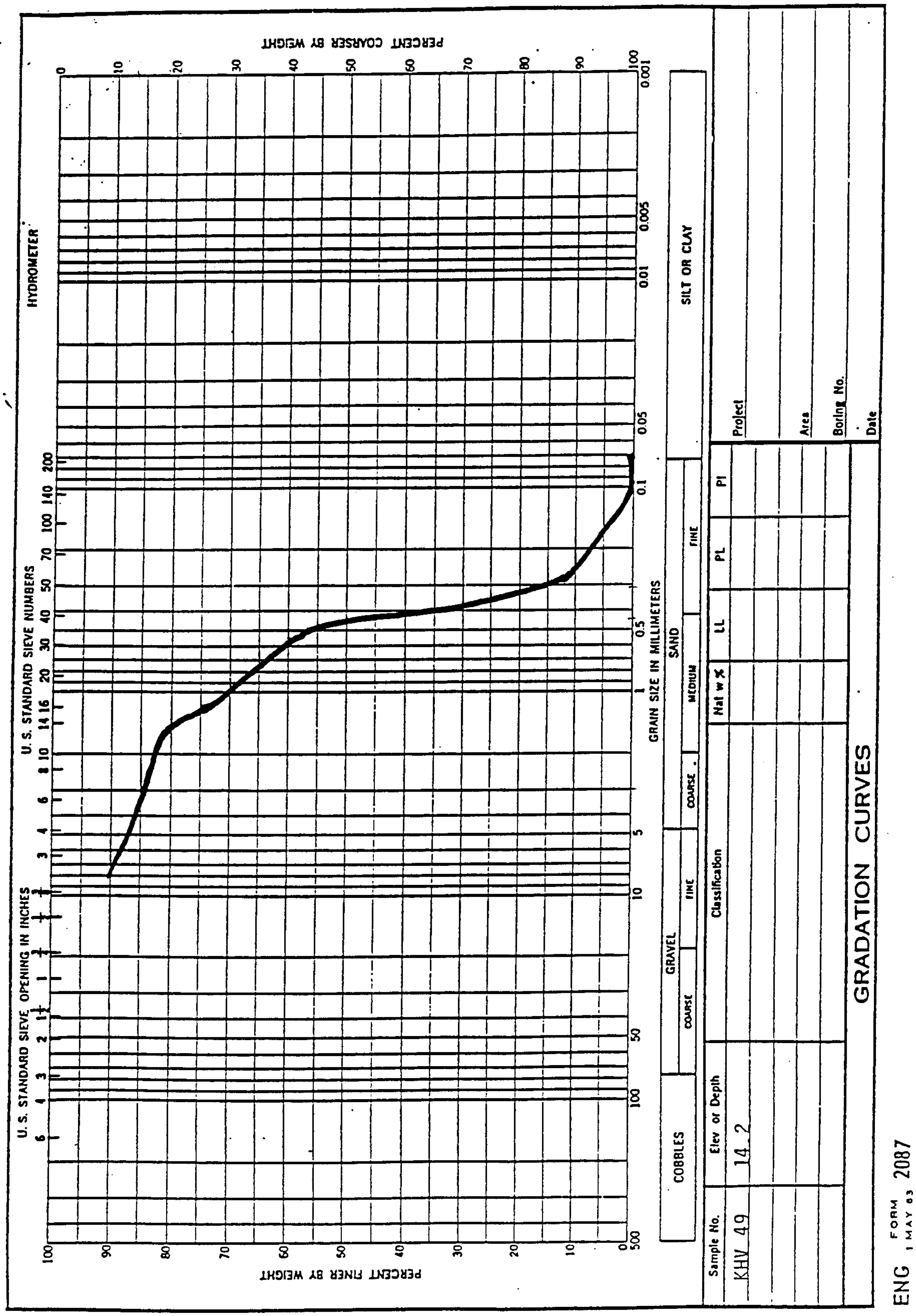
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 49
11.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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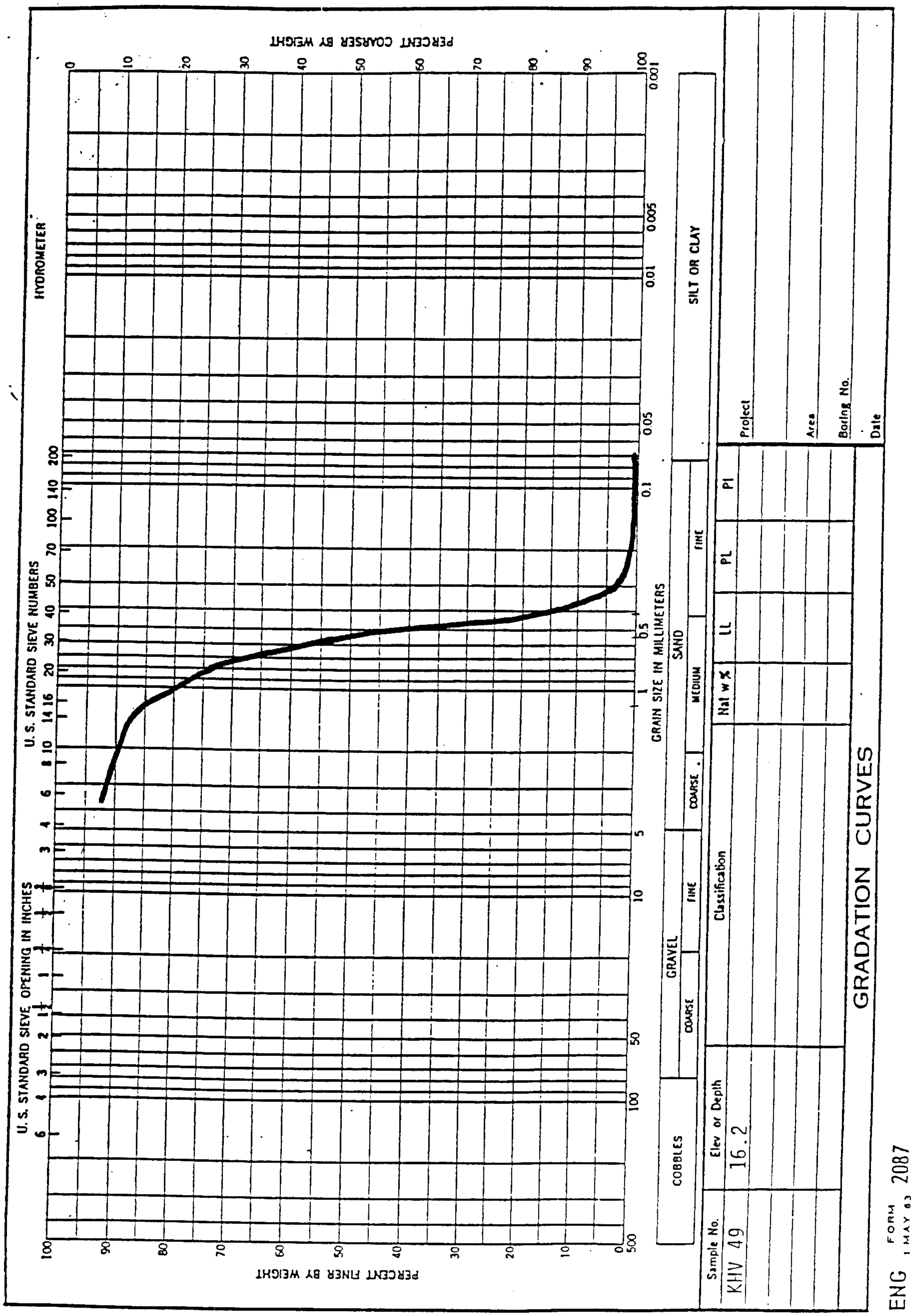
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 49
14.2
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
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SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
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Classification
Nat w %
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PL
PI
Project
Area
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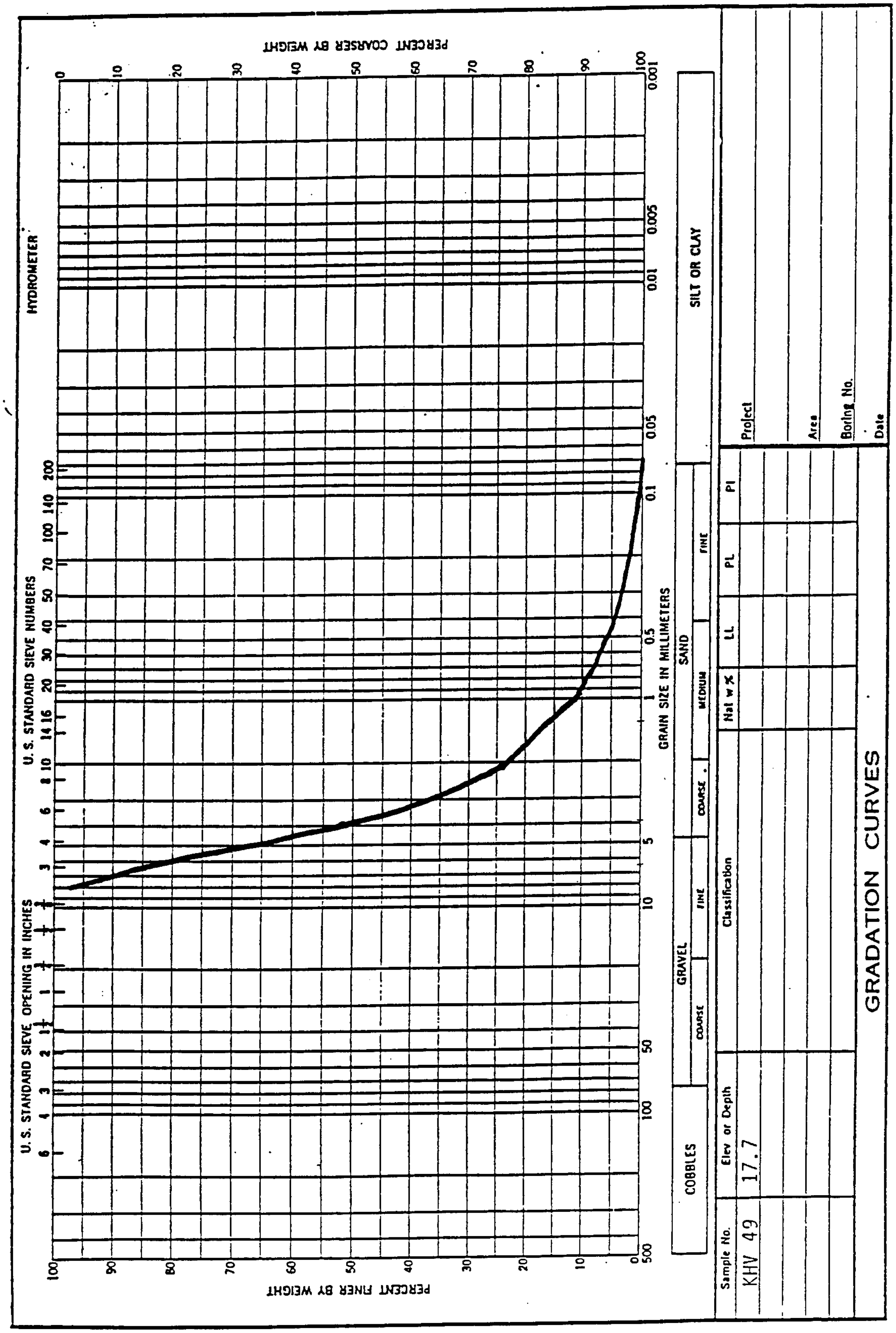
Date
ENG FORM 1 MAY 63 2087



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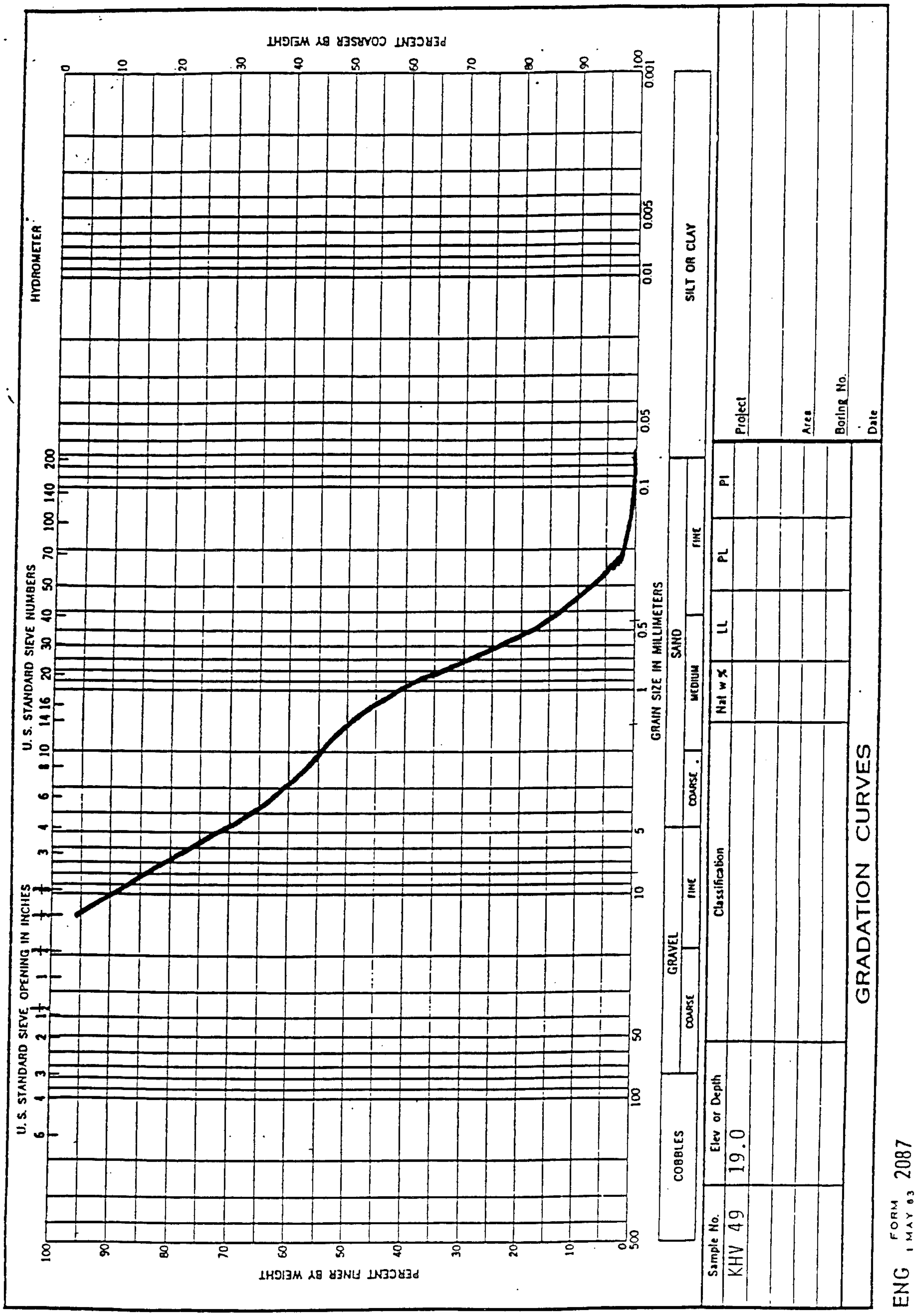
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U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 49
Elev or Depth
19.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 771923.50E, 198411.60N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-50	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [X] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole — Started 6/11/93 — Completed 6/11/93
	17. Elevation Top of Hole -23.6'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	19. Signature of Inspector JV D-JK
9. Total Depth of Hole 18 ft	

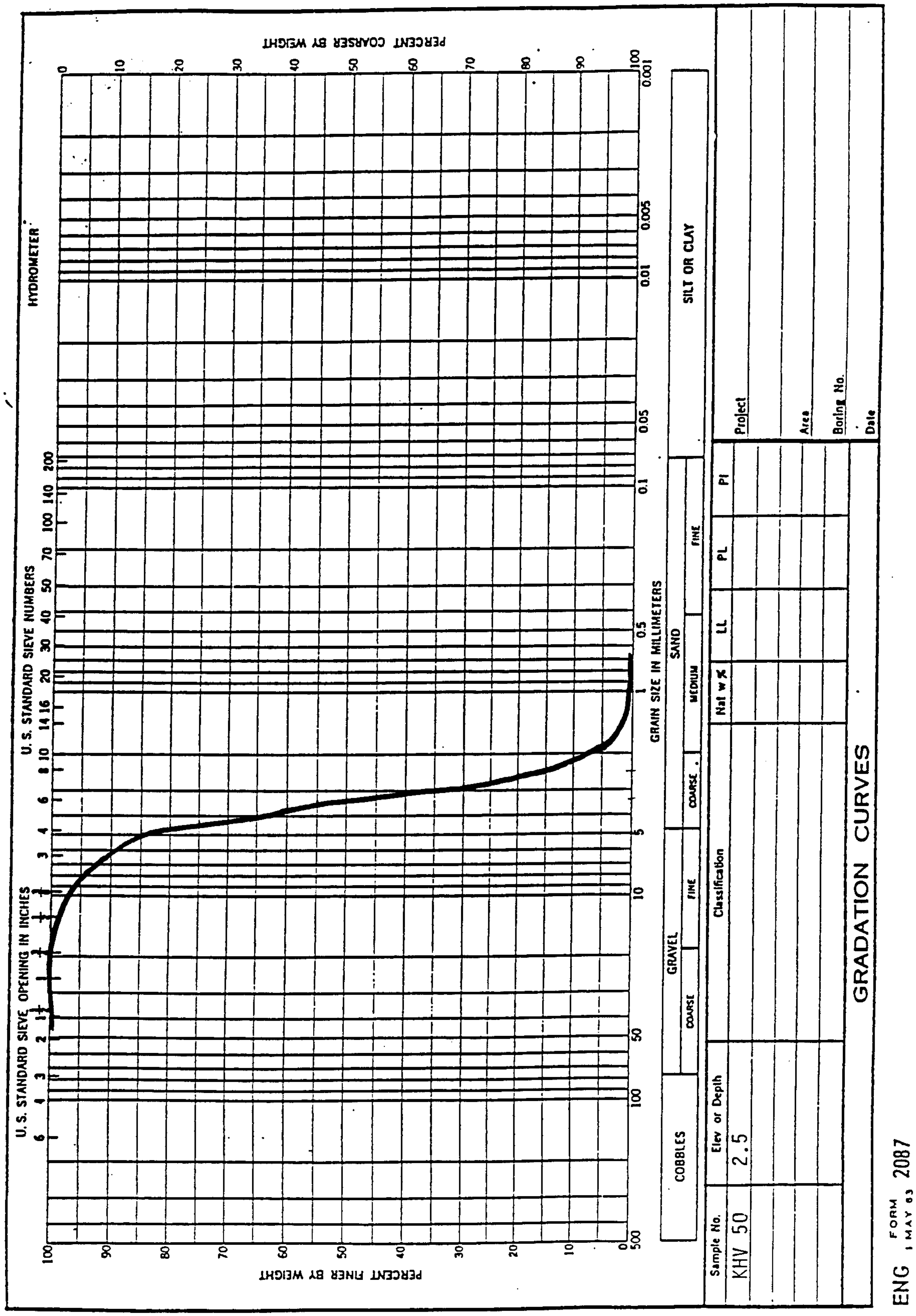
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–2.3	CL	Gray, stiff mud; little moisture	100		
	2.3–3	SP	Coarse sand and gravel; abundant shell fragments; wet			Sample at 2.5'
	3–10	SP	Brown, coarse to medium sand; few shells	100		Sample at 5.0'
	9	SP	Brown, coarse sand; few shells	100		Sample at 10.0'

ENG FORM 1836 Project Hole No.

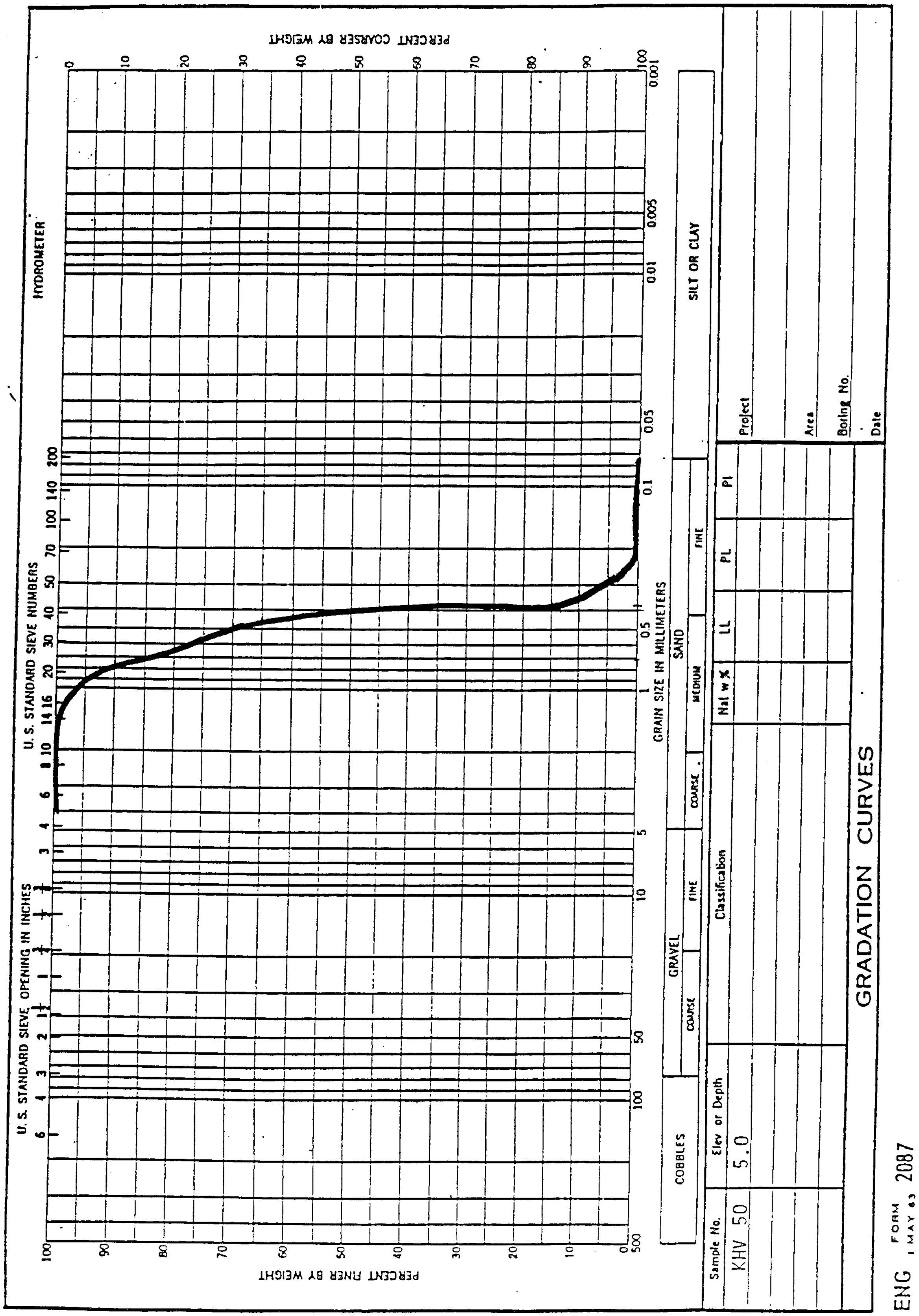
Drilling Log (Cont Sheet)	Elevation Top of Hole -23.6'	Hole No. KHV-50
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11	SP	Brown, coarse sand; some shells	100		Streaks of a dark mineral
	12					
	13					
	14	SP	Light brown sand; some shells	100		Sample at 14.0'
	15	SP	Gray-brown, coarse sand; some shells; traces of a heavy mineral			
	16					
	17			100		
	18		18 ft Recovery			Sample at 18.0'
	19					
	20					
	21					

NG FORM 1836 Project Hole No.



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 50
Elev or Depth
2.5
Classification
Nat w%
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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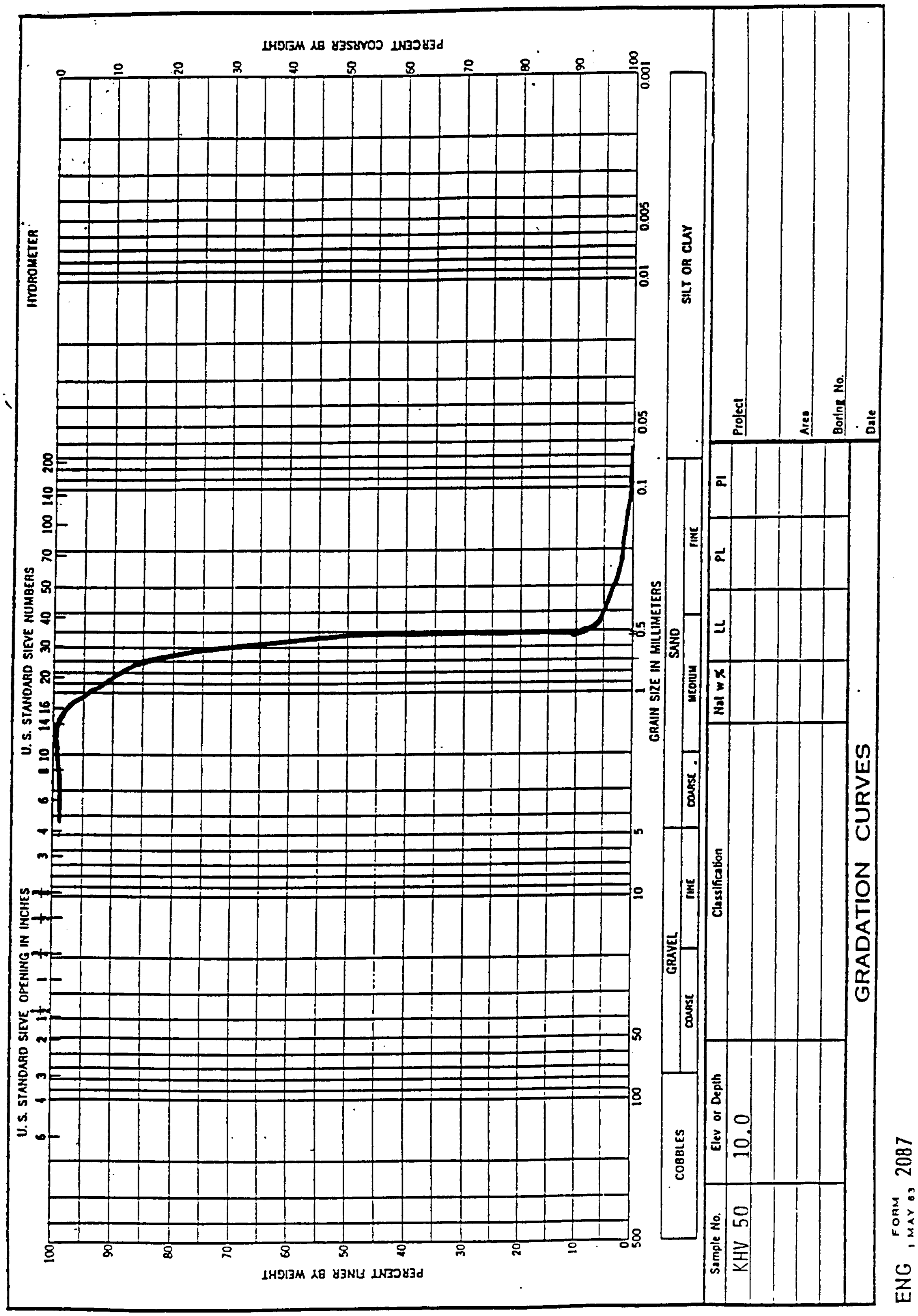
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 50
5.0
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
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U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 50
Elev or Depth
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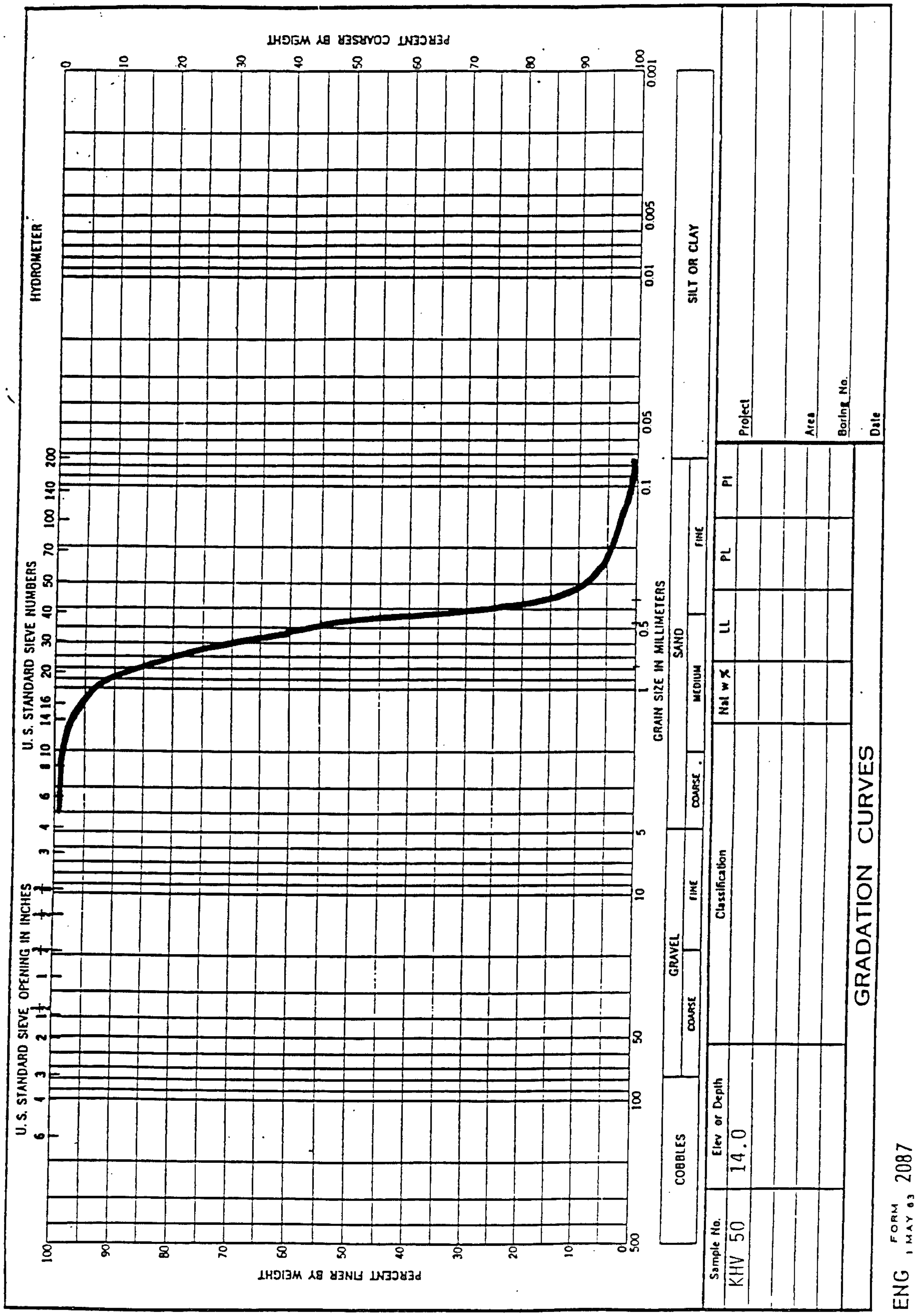
Classification
Nat w%
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 2087
1 MAY 63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PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
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Classification
Nat w %
LL
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Boring No.
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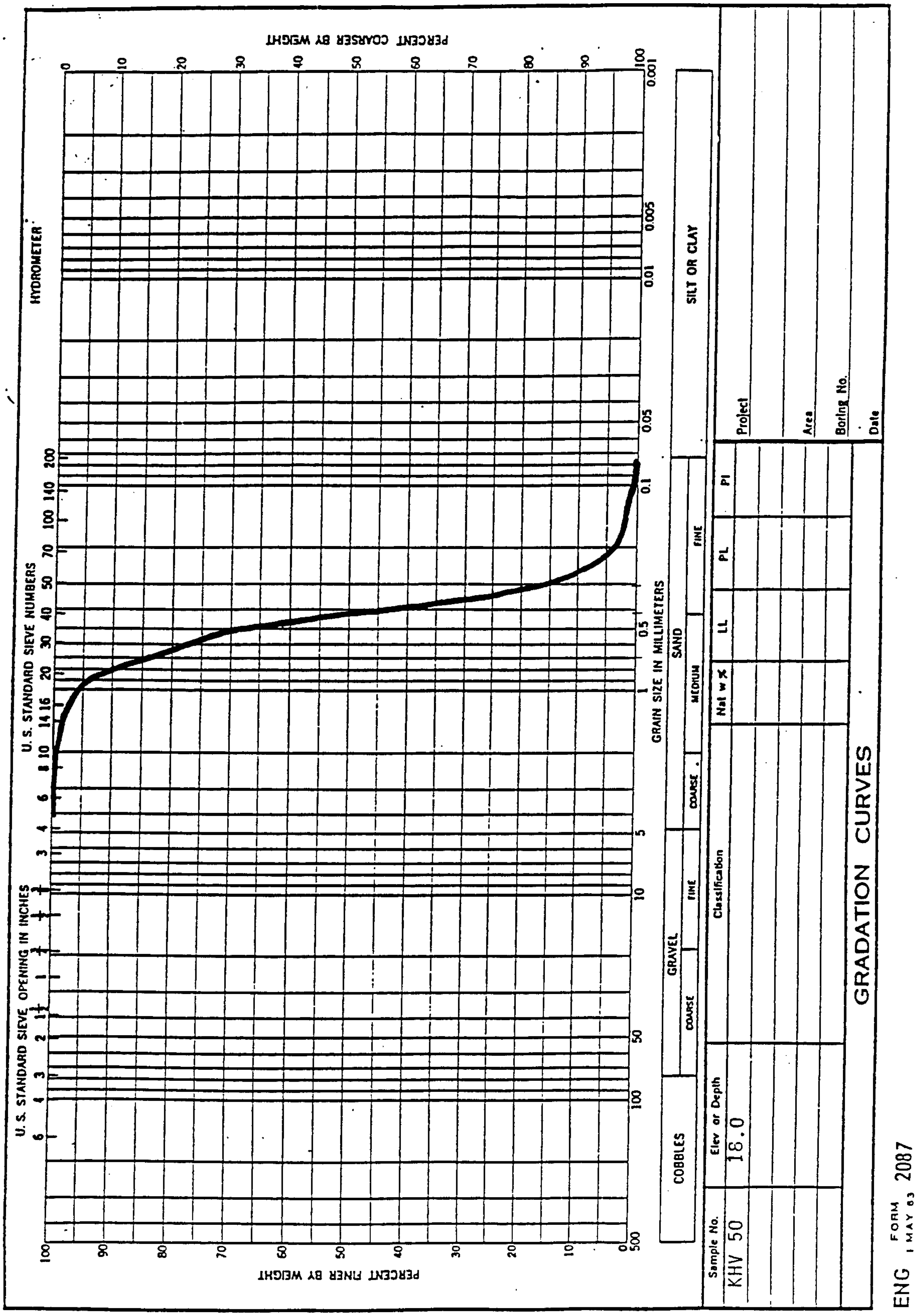
ENG FORM 1 MAY 63 2087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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 50
Elev or Depth
18.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 772592.60E, 181912.80N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-51 Run 1	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole ☒ Vertical ☐ Inclined ______ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/10/93 — Completed 6/10/93
7. Thickness of Overburden	17. Elevation Top of Hole -36.3'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 11.5 ft	19. Signature of Inspector JV GZ

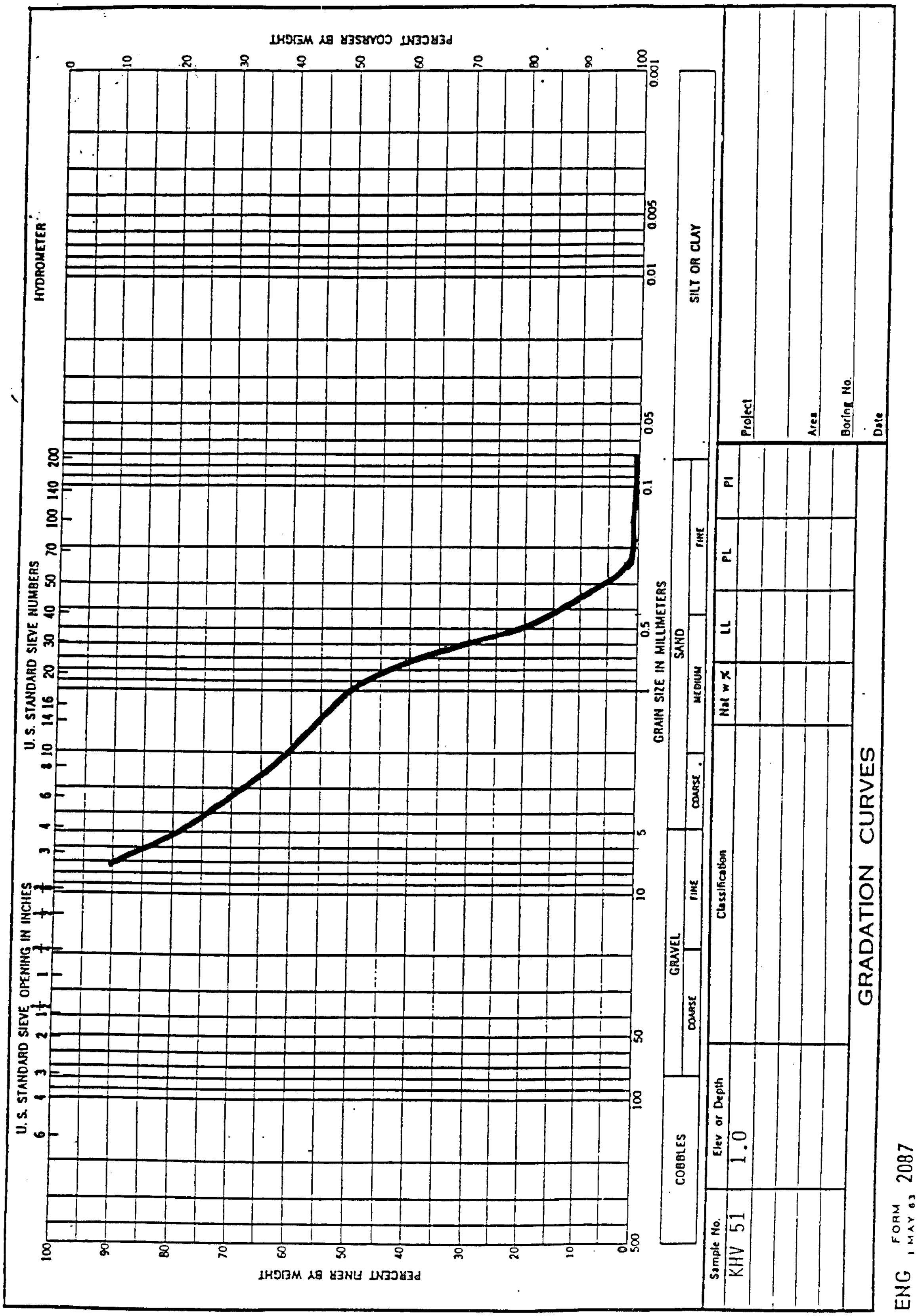
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0					2 runs, apparently
	0–1.5	GW	Coarse, rounded gravel and course sand; wet; trace of shells			Sample at 1.0'
	1.5–3	SW	Brown, coarse sand; some gravel; wet			Sample at 2.0' Sample at 2.7'
	3–5	SP	Brown sand			Sample at 3.6'
	5–6	SC	Gray clayey sand, moist			Sample at 5.0'
	6–10	SP	Clean, white, medium sand			Sample at 6.0'
	9	SP				
	10					End Run 1 at 11.5'

ENG FORM 1836 | Project | Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -36.3'		Hole No. KHV-51 Run 1
Project KHV	Installation		Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SW	Light gray, medium to coarse sand; trace gravel			Run 2 begins at 10.0'
	11					Sample at 11.5'
	12	SP	Silty, medium sand			
	13					Sample at 13.0'
	14	SW	Gray, coarse sand and gravel; trace of silt			Sample at 14.0'
	15	SW	Medium to coarse sand			
	16	SW	Medium sand			Sample at 16.0'
	17		17.5 ft Recovery			
	18					
	19					
	20					
	21					

NG FORM 1836 Project Hole No.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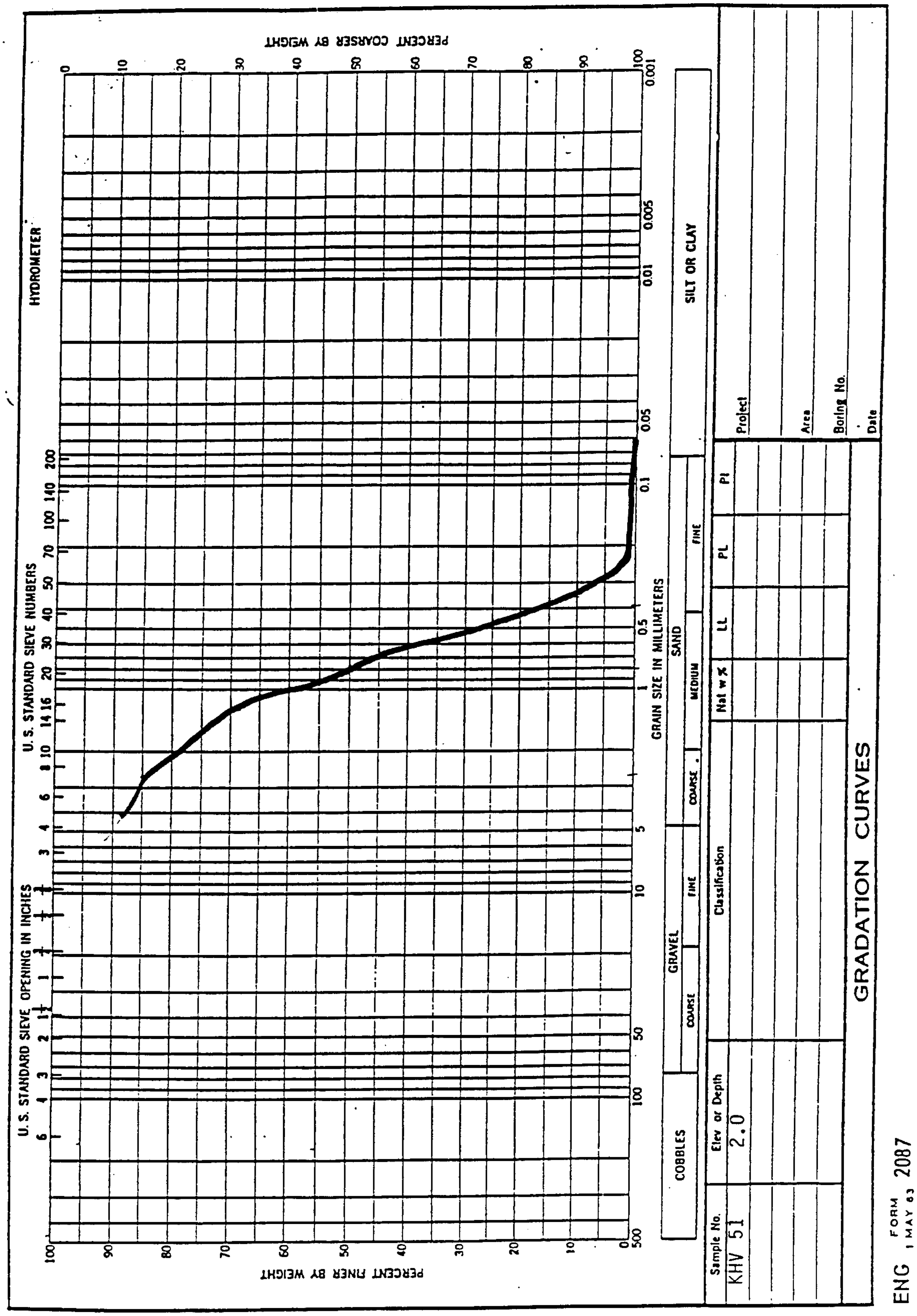
PERCENT FINER BY WEIGHT
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
1.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
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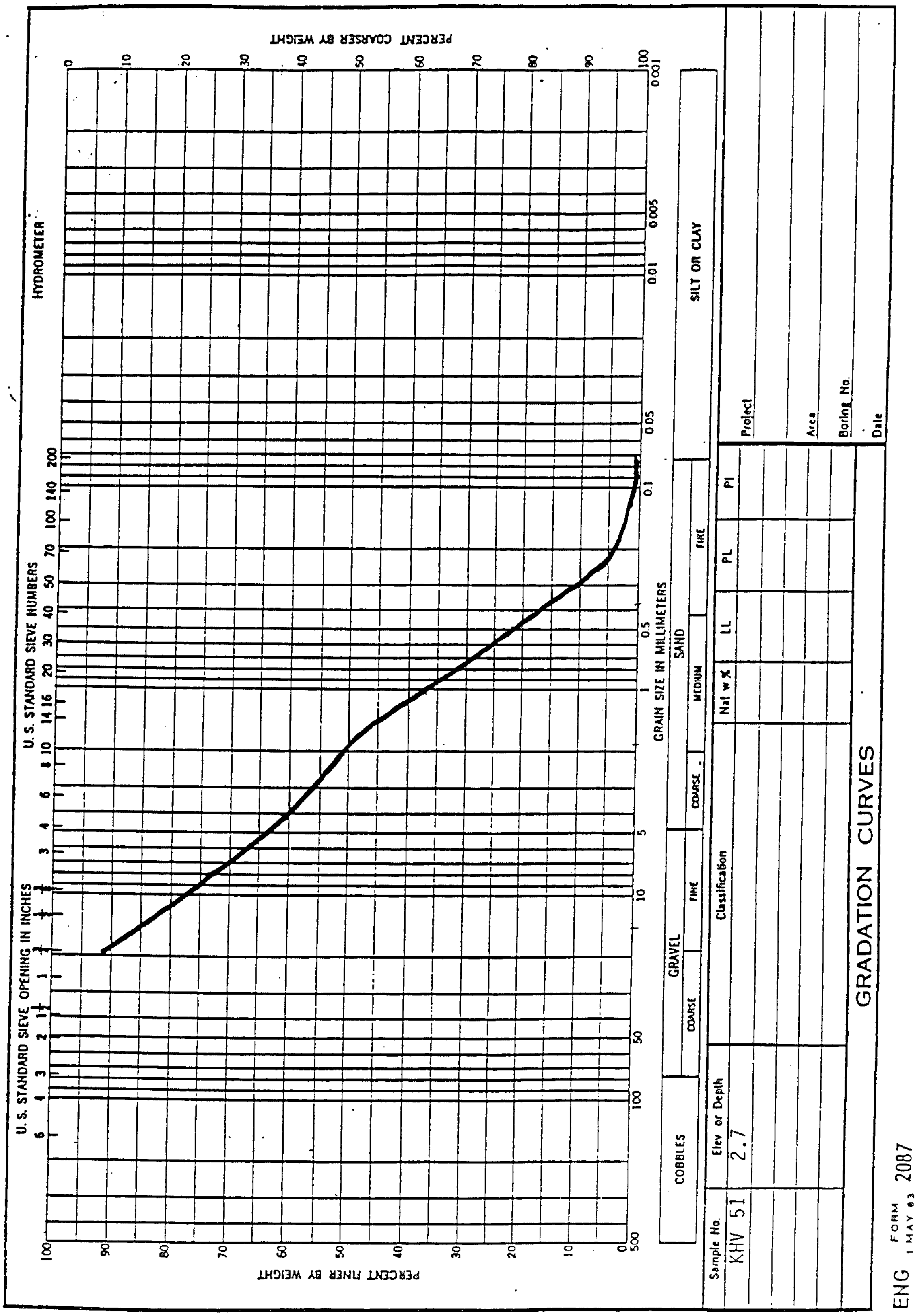
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
2.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
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PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
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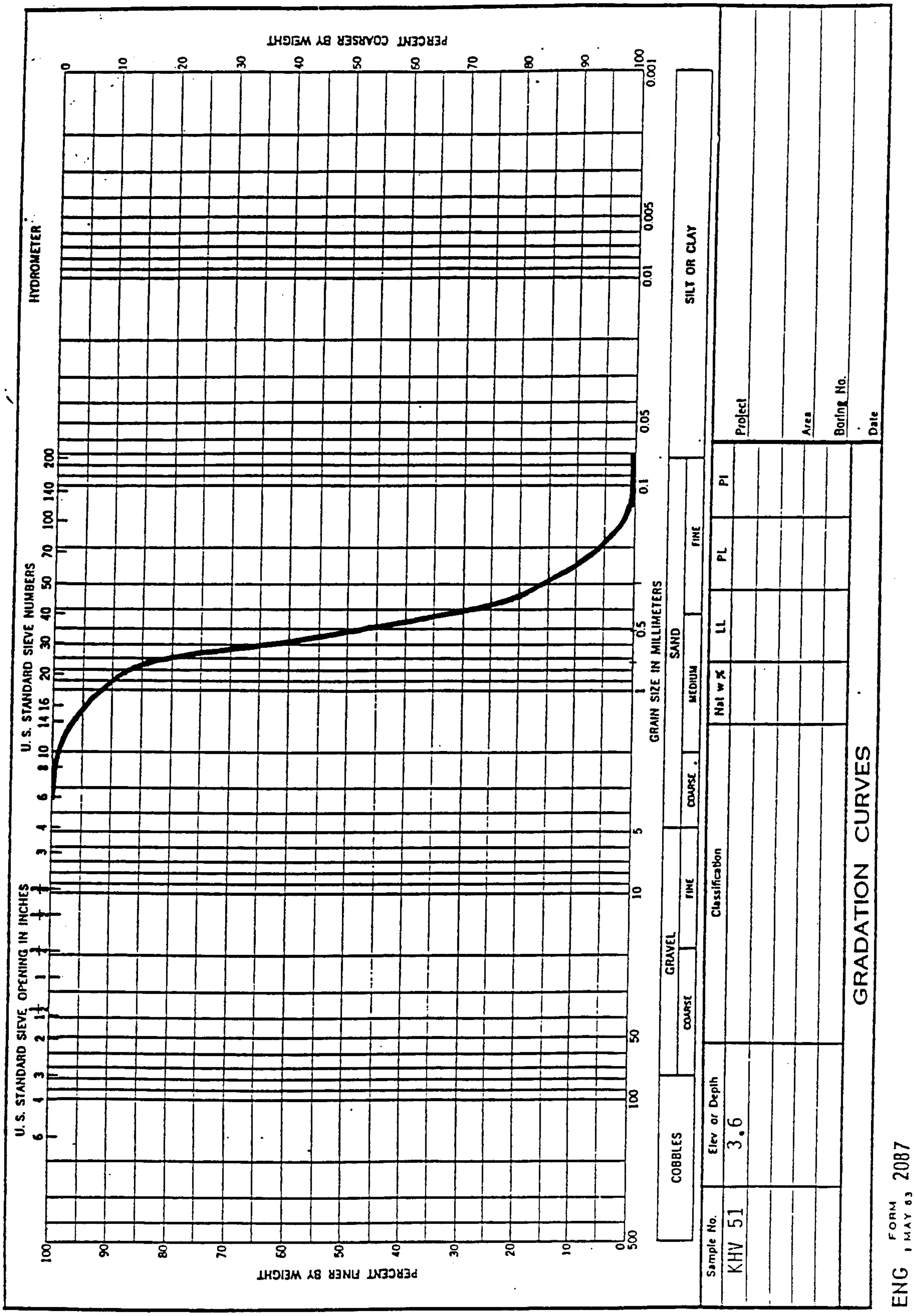
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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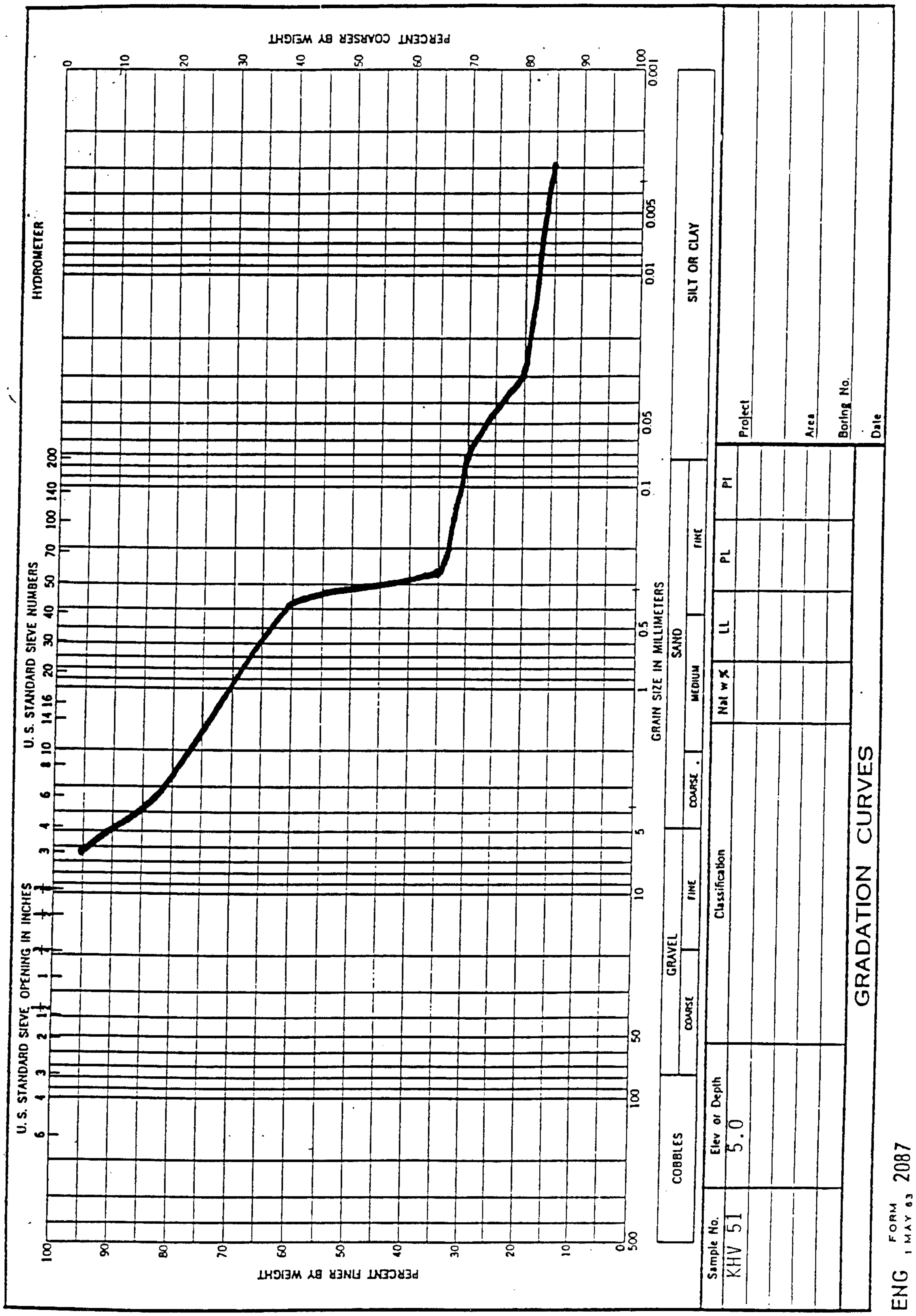
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
3.6
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
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SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
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Classification
Nat w %
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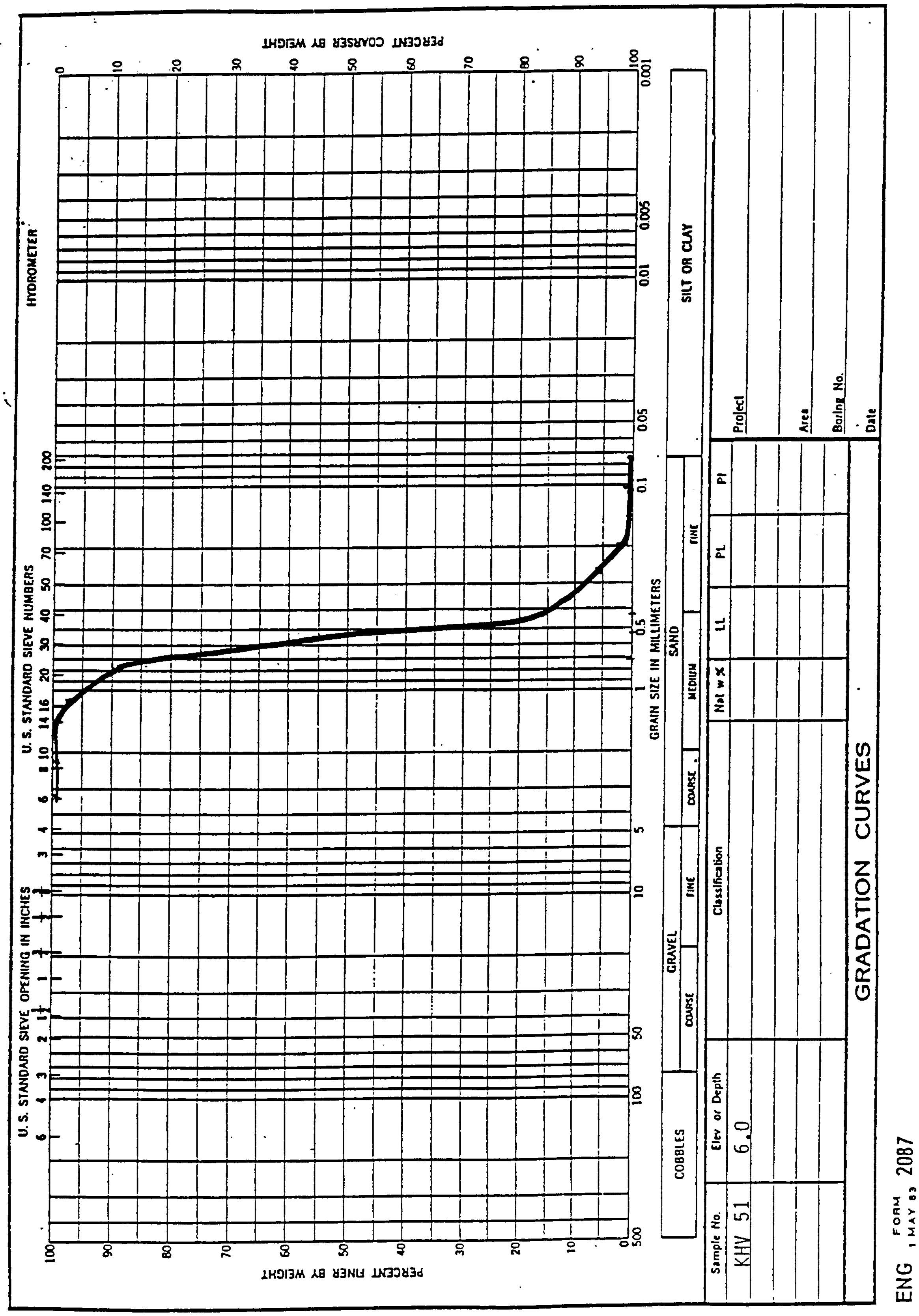
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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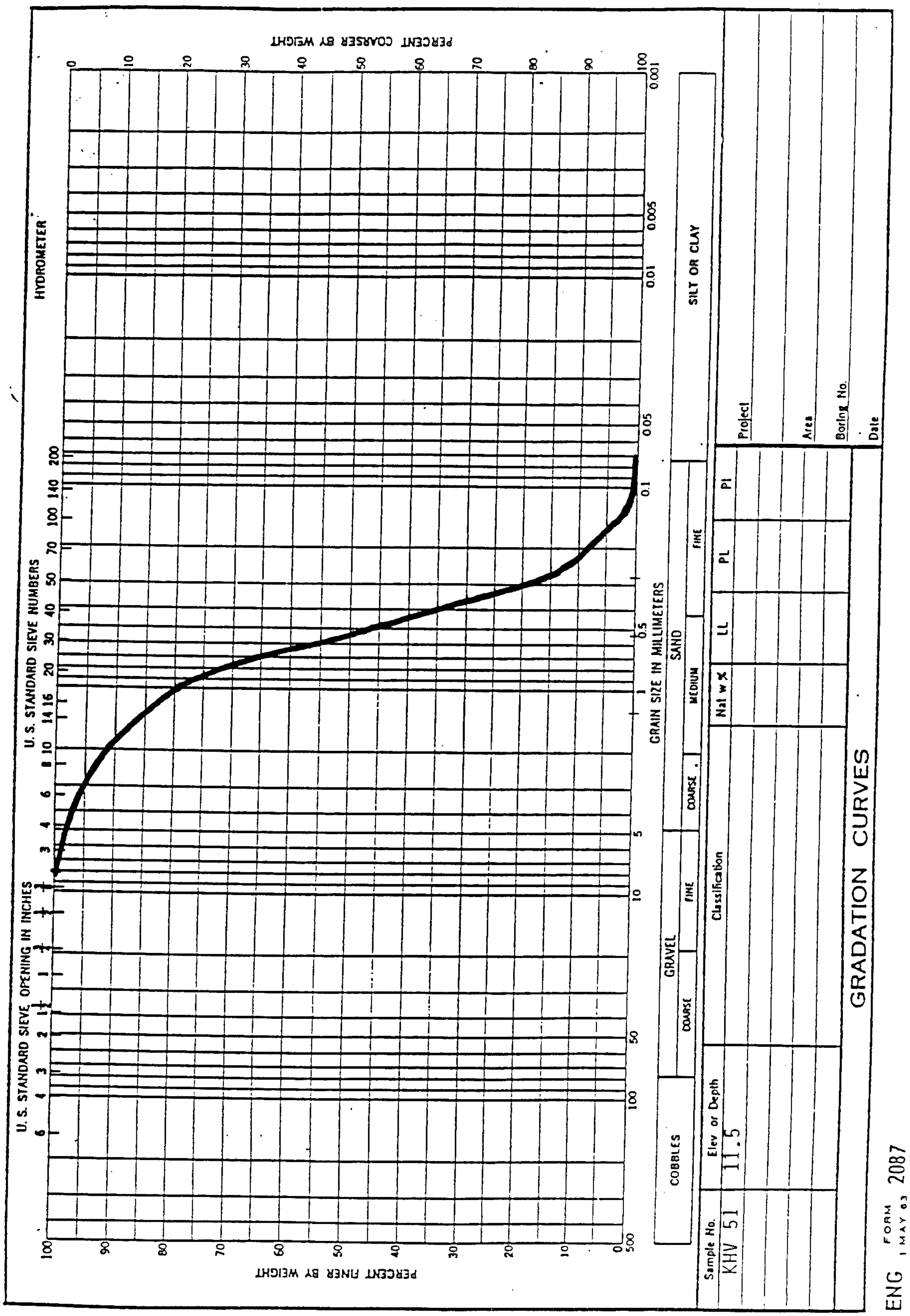
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 51
6.0
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
Elev or Depth
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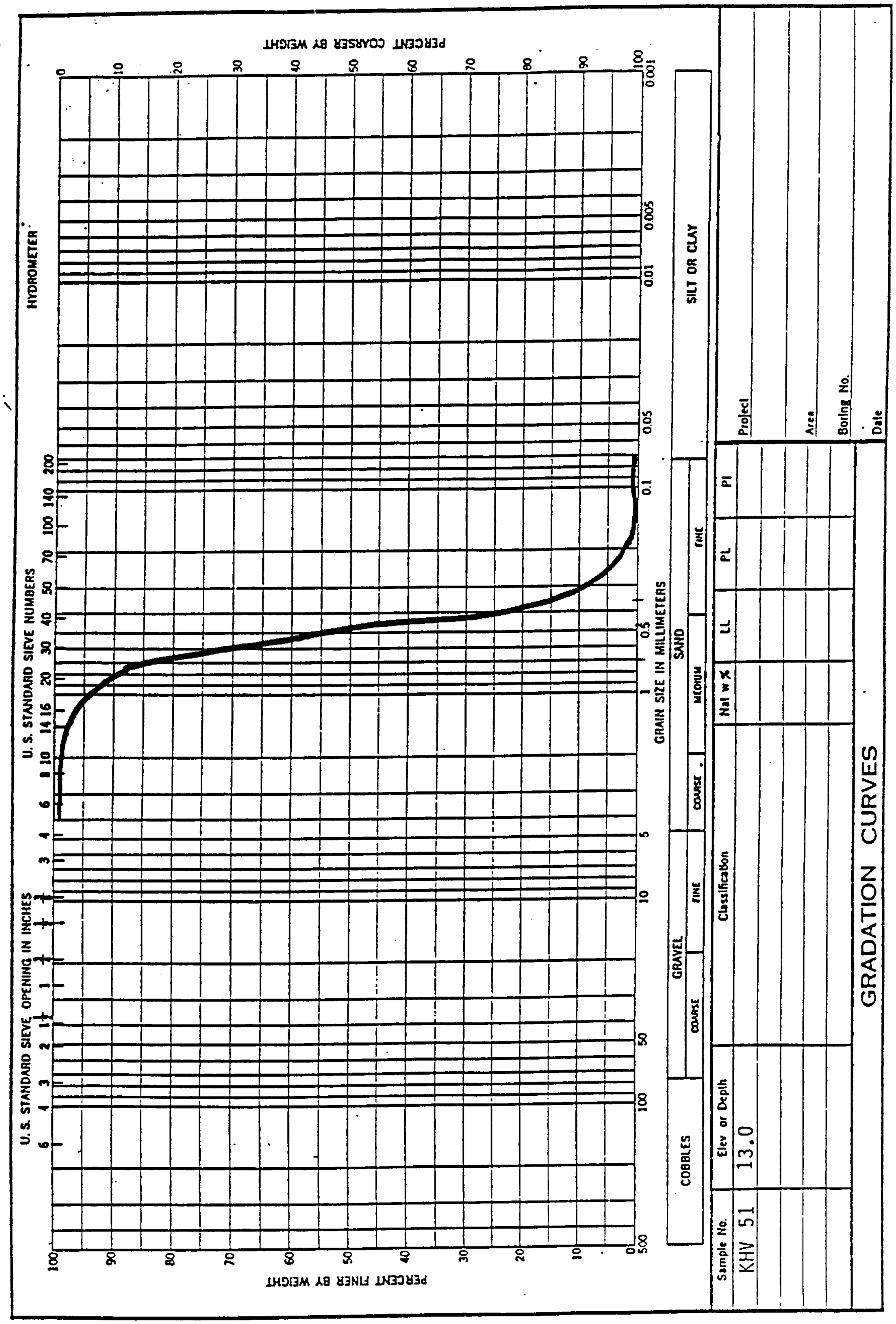
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE OPENING IN INCHES
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PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 51
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Classification
Nat w %
LL
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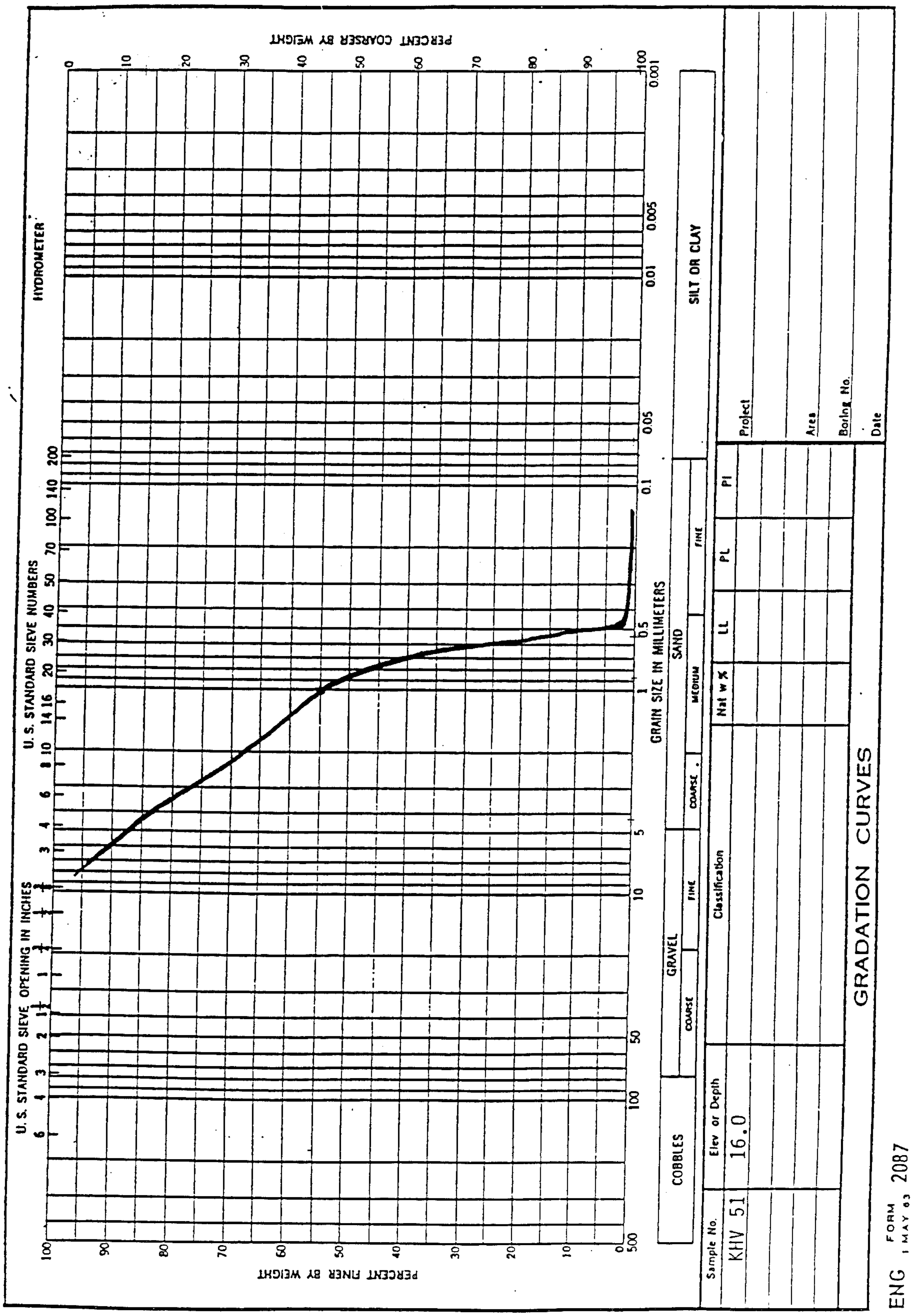
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 51
16.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	1 of 2 Sheets
2. Location 772754.50E, 218753.70N	10. Size and Type of Bit
Drilling Agency Alpine Ocean Seismic Survey, Inc.	11. Datum for Elevation Shown (TDM or MSL) MLLW
4. Hole No. (As shown on drawing title) KHV-52 Run 1	12. Manufacturer's Designation of Drill
5. Name of Driller	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	14. Total No. of Core Boxes
7. Thickness of Overburden	15. Elevation Ground Water
8. Depth Drilled Into Rock	16. Date Hole — Started 6/11/93 — Completed 6/11/93
9. Total Depth of Hole 12.2 ft	17. Elevation Top of Hole -39.0'
	18. Total Core Recovery for Boring %
	19. Signature of Inspector JV GZ

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–2.5	SW	Brown, coarse, rounded sand; some round gravel; wet	100		18' penetration; 12.2' recovery Run 1: 0'–2.5' + 7.2'–12.2' Run 2: 2.2'–7.2' and 10'–15' Sample at 1.5'
	2.5–7.2		No core available	0		
	7.2–10	SW	Brown and gray, medium to coarse sand; slightly clayey; trace of gravel	100		

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -39.0'			Hole No. KHV-52 R1		
Project KHV			Installation		Sheet 2 of 2 Sheets	
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Yellow, coarse sand; wet; trace of dark mineral			Sample at 10.6'
	11					
	12		End of Run 1			
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21.					

NG FORM 1836 Project Hole No.

Drilling Log		1 of 2 Sheets
1. Project KHV	10. Size and Type of Bit	
2. Location 772824.80E, 218794.40N	11. Datum for Elevation Shown (TDM or MSL) MLLW	
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill	
4. Hole No. (As shown on drawing title) KHV-52 Run 2	13. Total No. of Overburden Samples Taken	Disturbed / Undisturbed
5. Name of Driller	14. Total No. of Core Boxes	
	15. Elevation Ground Water	
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	16. Date Hole	Started 6/11/93 / Completed 6/11/93
7. Thickness of Overburden	17. Elevation Top of Hole -38.6'	
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %	
9. Total Depth of Hole 20 ft	19. Signature of Inspector JV GZ	

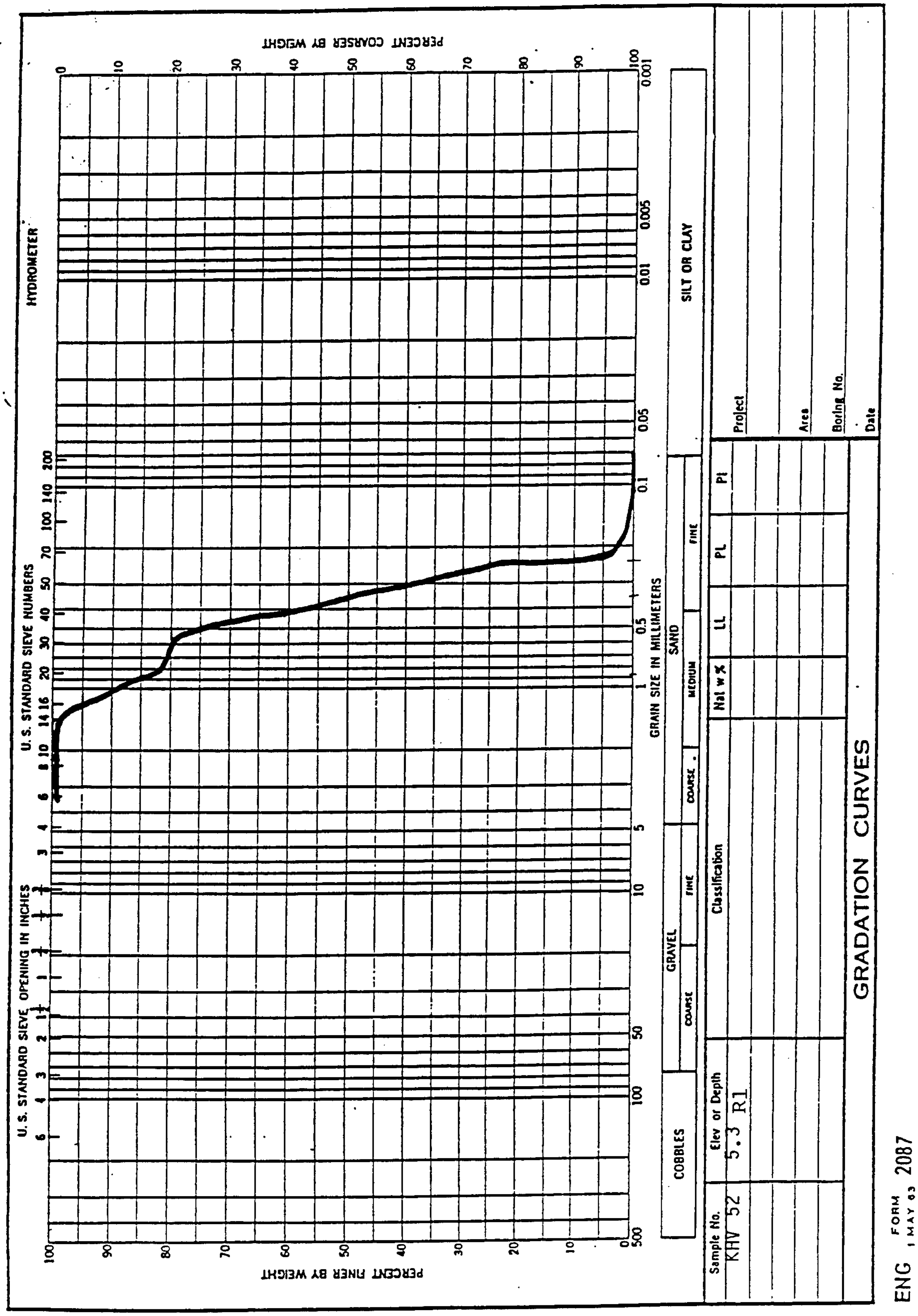
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–2.3		No core available			
	2.3–4.1	GP	Brown, coarse sand and gravel (50–50)			Sample at 2.7'
	4.1–4.9	SW	Tan, coarse sand			
	4.9–6.0	SP	Yellow to light gray, medium to coarse sand			Sample at 5.3'
	6.0–7.3		Light gray, fine to coarse sand; some gravel			Sample at 6.6'
	7.3–8.7	GW	Brown, coarse, round gravel; some coarse sand			Sample at 8.5'
	8.7–10	GW	As above, some silt; wet			

ENG FORM 1836 Project Hole No.

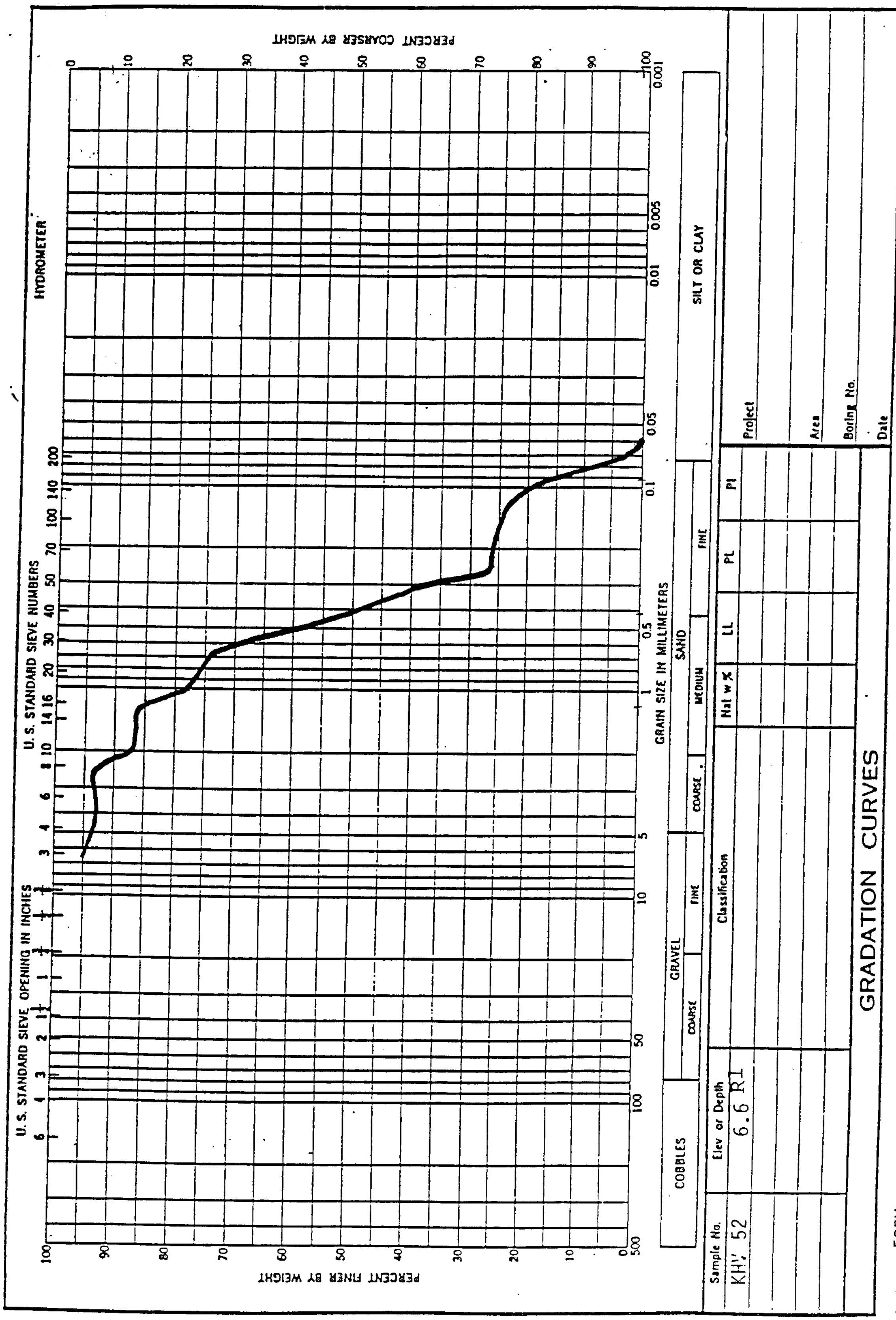
Drilling Log (Cont Sheet)	Elevation Top of Hole -38.6'	Hole No. KHV-52 R2
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10–11.9	SW	Yellow, medium sand; some rounded gravel			
	12	SP	Yellow, coarse sand; some clay laminations; some rounded gravel			
	13		Same composition, but color changed to orange			
	14		Dark gray, coarse sand with gravel			Sample at 14.4'
	15	SP	Yellow, medium to coarse sand and silt			
	17	SP	Yellow, coarse sand			
	18		Light brown, coarse sand; lenses of gray, silty sand			Sample at 18.2'
	19–20		Yellow, coarse sand; some silt; wet			
			20.5 ft Recovery			
	21					

NG FORM 1836 Project Hole No.



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 52
Elev or Depth
5.3 R1
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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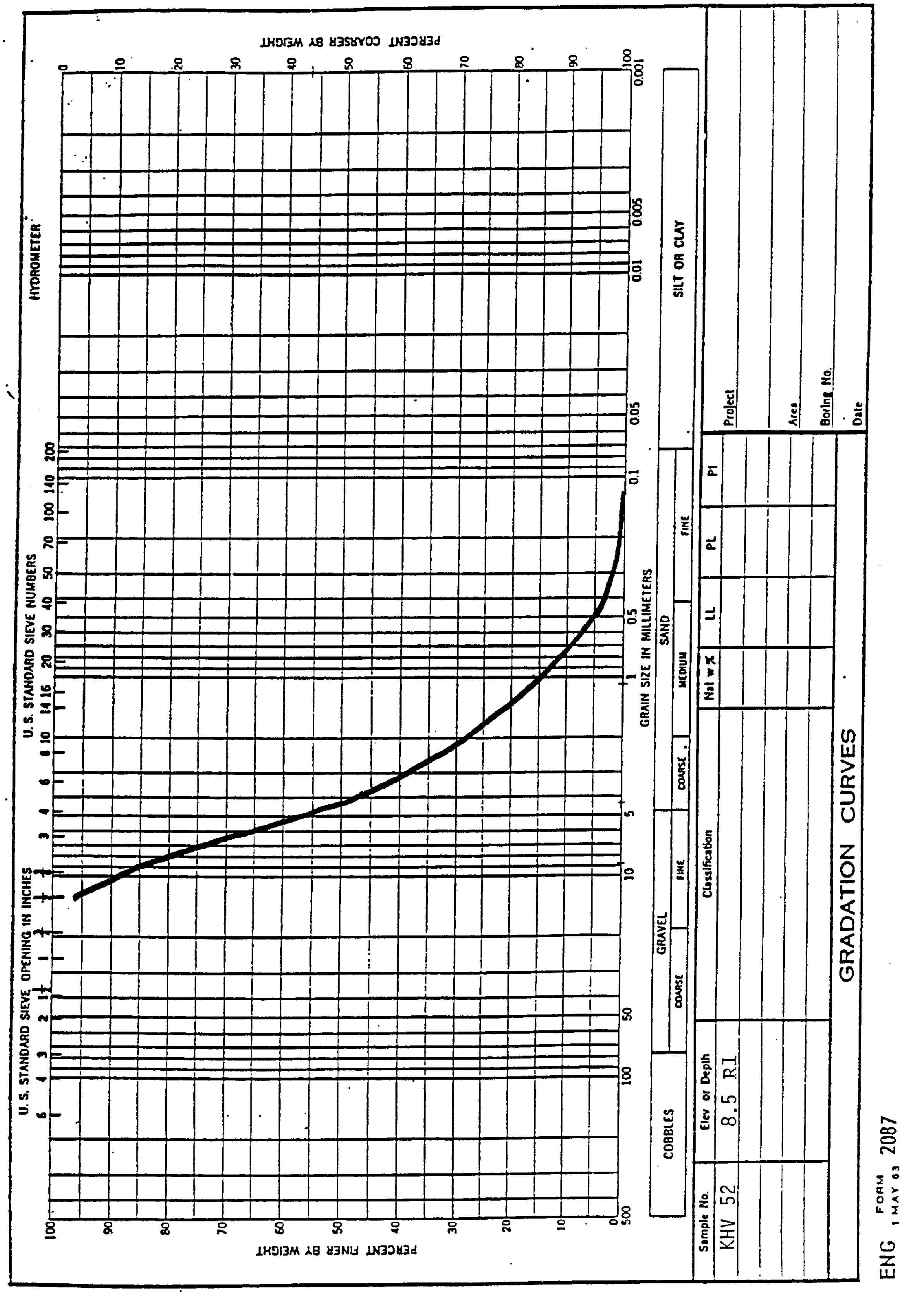
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 52
6.6 R1
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE NUMBERS
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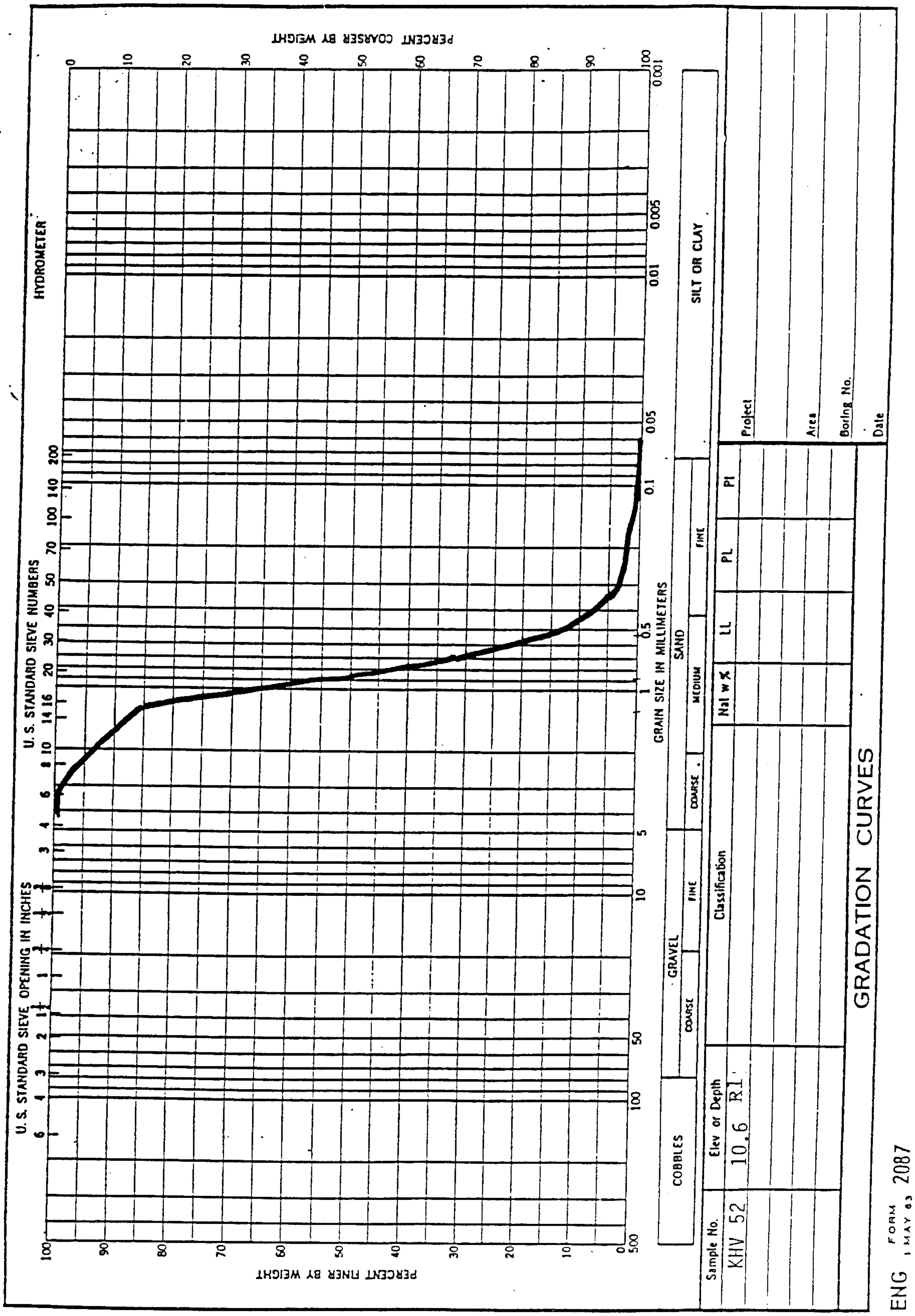
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 52
8.5 R1
GRADATION CURVES
ENG FORM 1 MAY 63 2087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U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
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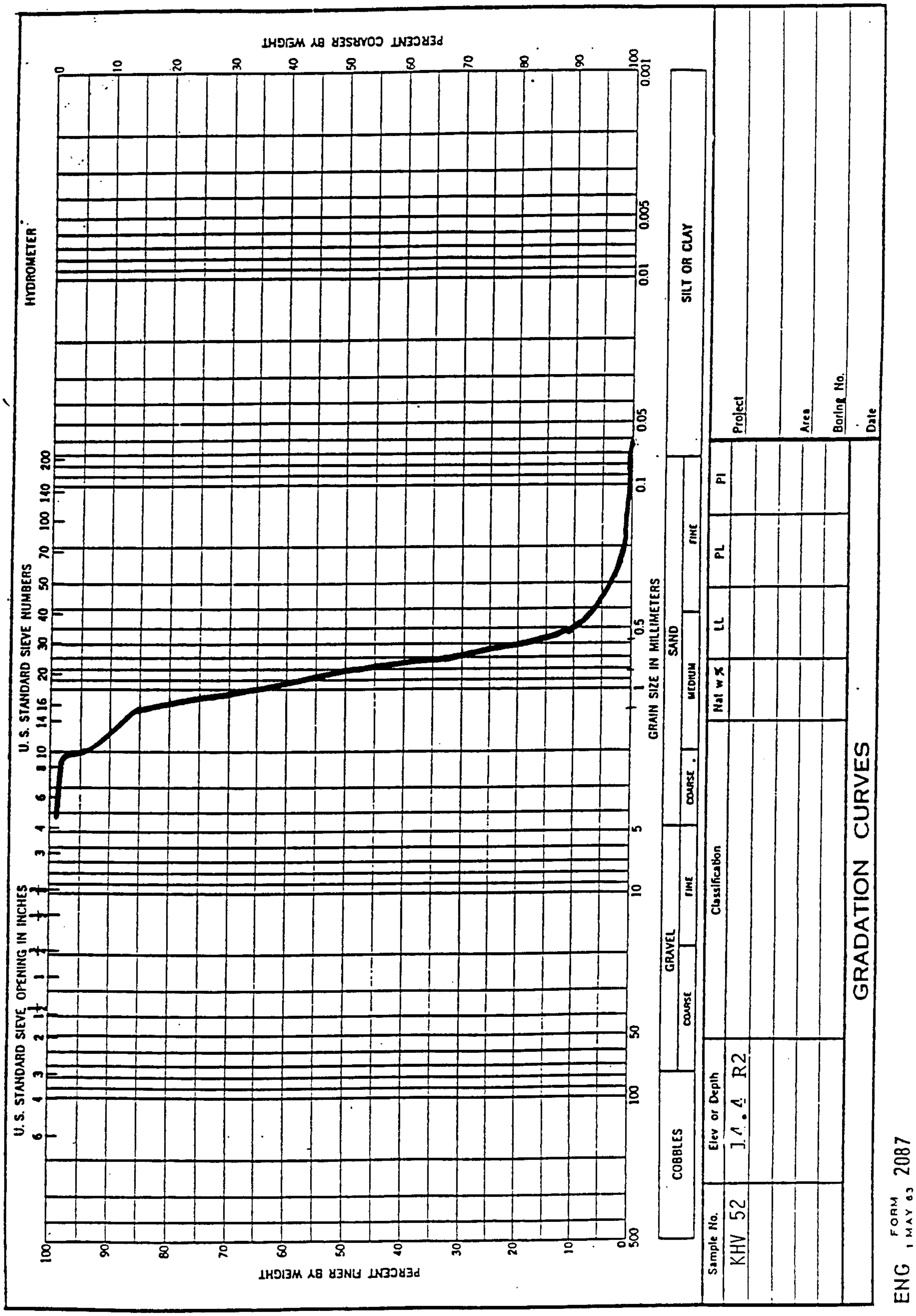
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 52
Elev or Depth
10.6 R1
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087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PERCENT COARSER BY WEIGHT
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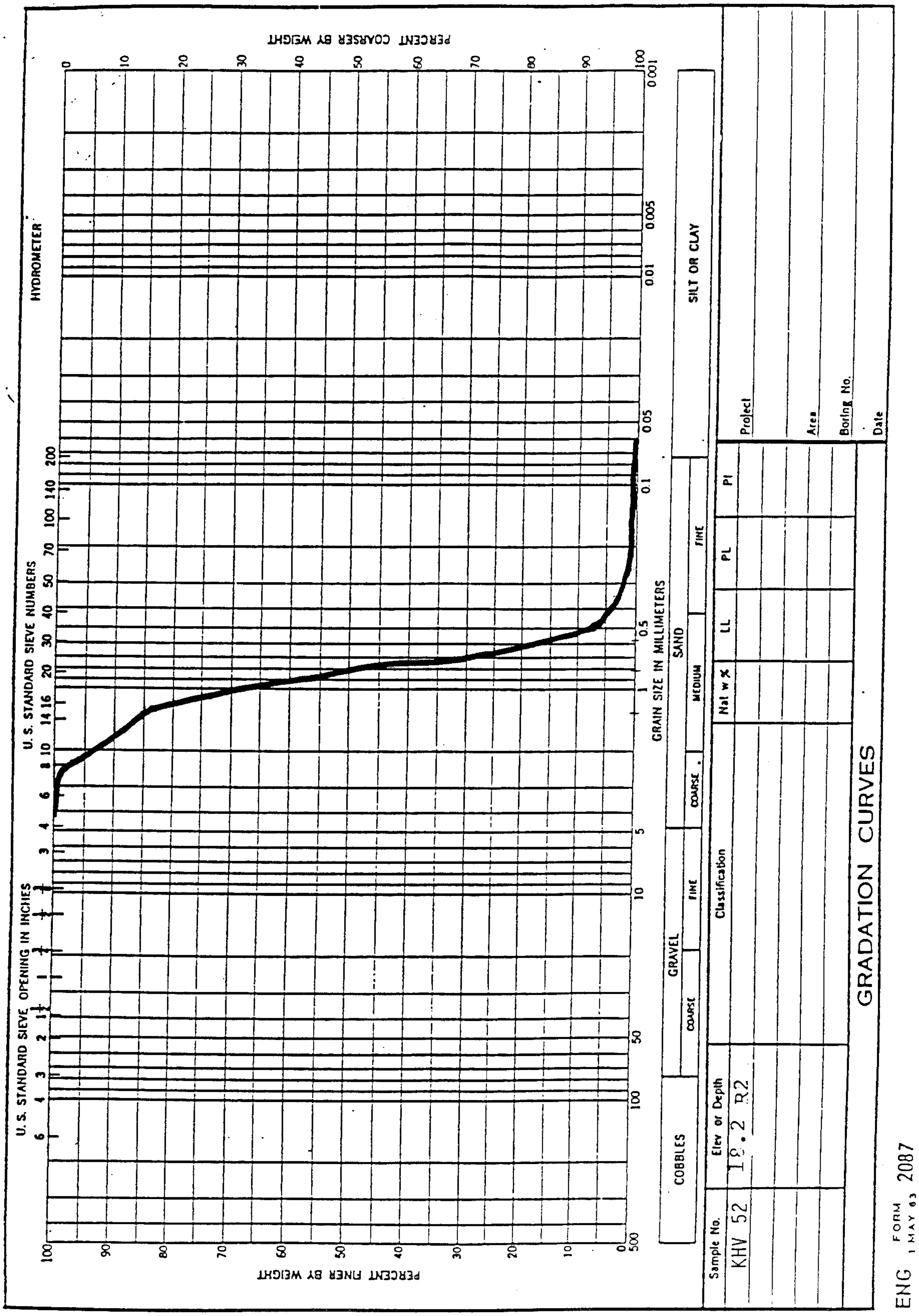
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
SAND
SILT OR CLAY
COARSE
FINE
MEDIUM
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
KHV 52
14.4 R2
ENG FORM 1 MAY 63 2087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HYDROMETER
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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 52
Elev or Depth
18.2 R2
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 775645.90E, 226680.80N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-53	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	16. Date Hole — Started 6/10/93 — Completed 6/10/93
	17. Elevation Top of Hole -42.6'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	
9. Total Depth of Hole 20 ft	19. Signature of Inspector JV GZ

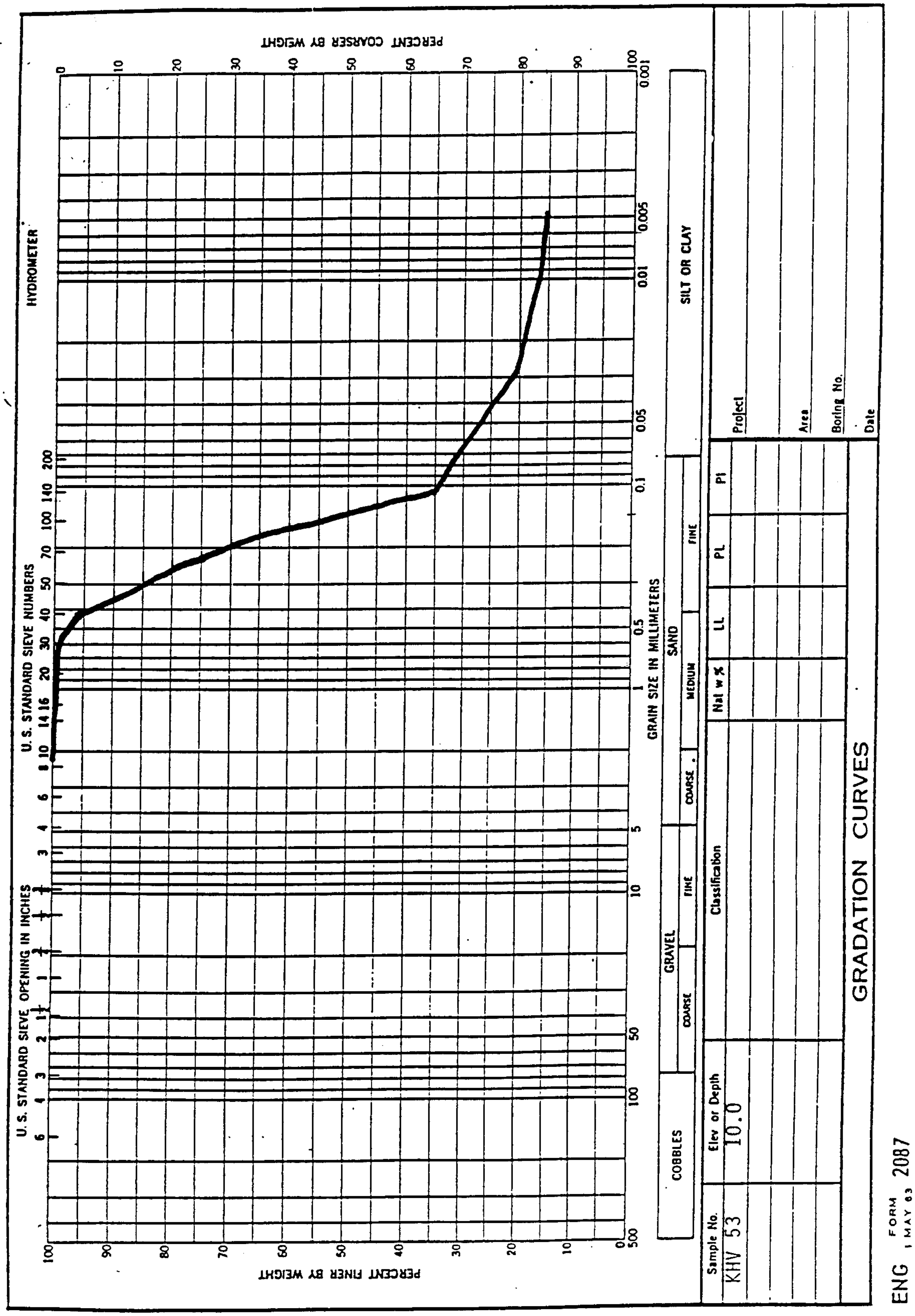
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0					Sample at 0.4'
		SC	Dark gray clayey sand	100		
	1					
	2					
	3					
	4	SC	Dark gray, clayey sand	100		
	5					
	6					
	7	SC	Dark gray, plastic clayey sand	100		
	8					
	9					
	10					Sample at 10.0'

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -42.6'	Hole No. KHV-53
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11	SC	Dark gray, clayey sand	100		
	12					
	13					
	14	SC	Dark gray, clayey sand	100		
	15					
	16					
	17	SC	Dark gray, clayey sand	100		
	18					
	19					
	20		20 ft Recovery			
	21					

NG FORM 1836 Project Hole No.


GRADATION CURVES
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 53
Elev or Depth
10.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087

Drilling Log	1 of 2 Sheets
1. Project KHV	10. Size and Type of Bit
2. Location 779070.80E, 185140.90N	11. Datum for Elevation Shown (TDM or MSL) MLLW
. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-54	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/16/93 — Completed 6/16/93
7. Thickness of Overburden	17. Elevation Top of Hole -40.3
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 19.8 ft	19. Signature of Inspector GZ D-JK

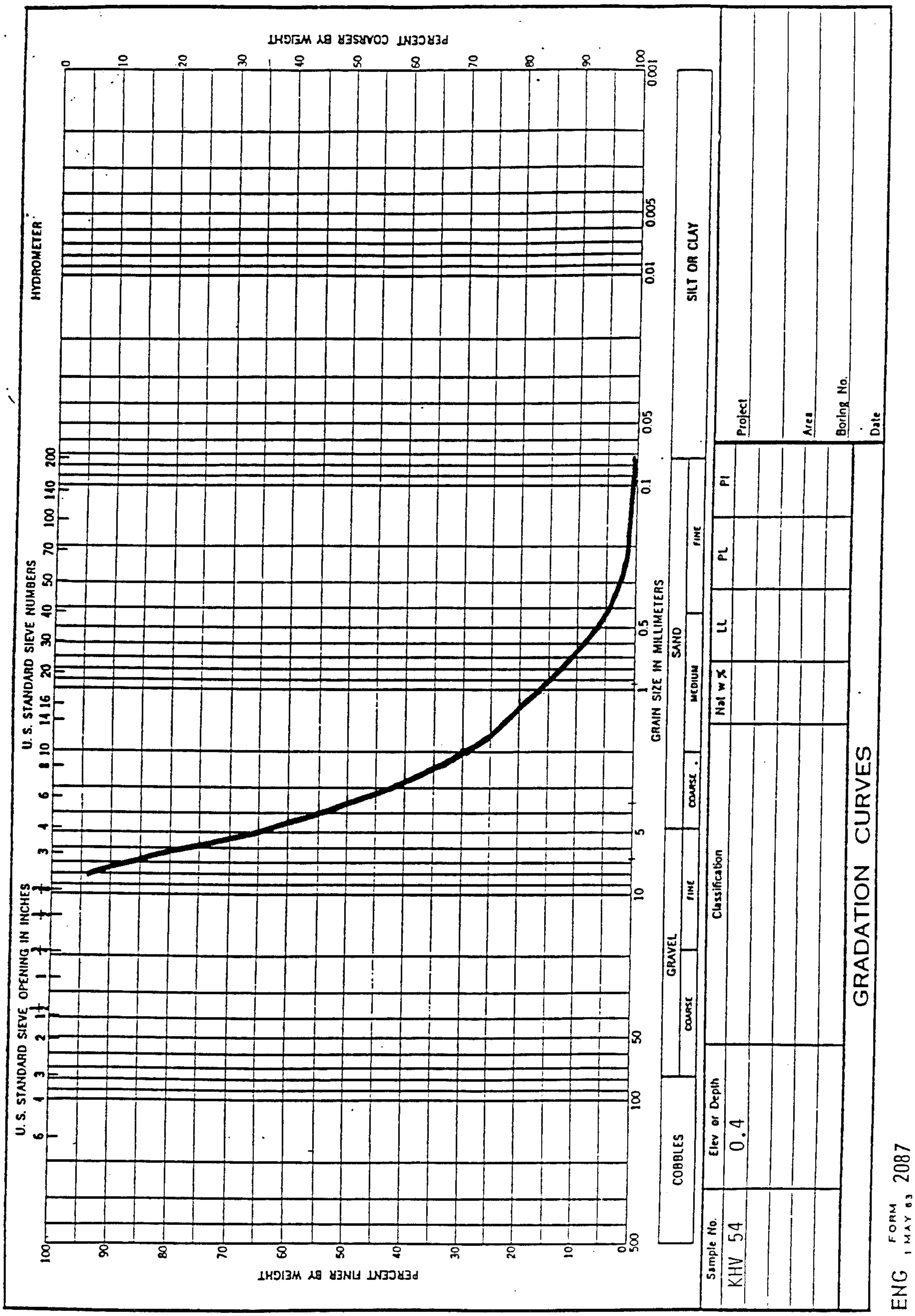
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0	SW	Clean, medium sand with gravel and shells	100		Sample at 0.4'
	1	SP	Dark gray, sand and gravel			Sample at 1.4'
	2					
	3	SC	Dark gray, clayey sand			
	4					Sample at 4.3'
	5	SC	Dark gray, clayey sand	100		
	6					
	7					
	8	SC	Dark gray, clayey sand			
	9			100		
	10					

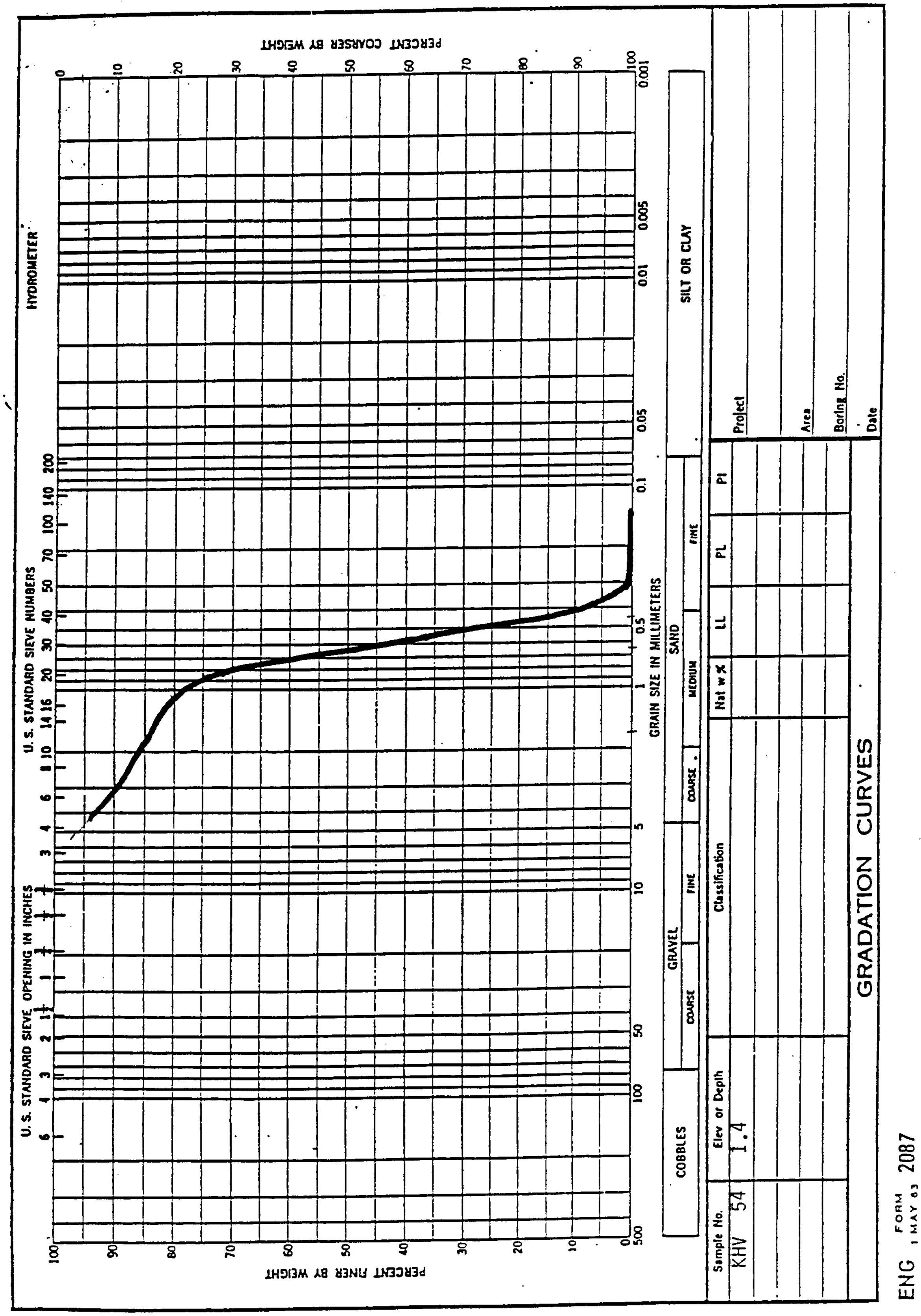
ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -40.3'	Hole No. KHV-54
Project KHV	Installation	Sheet 2 of 2 Sheets

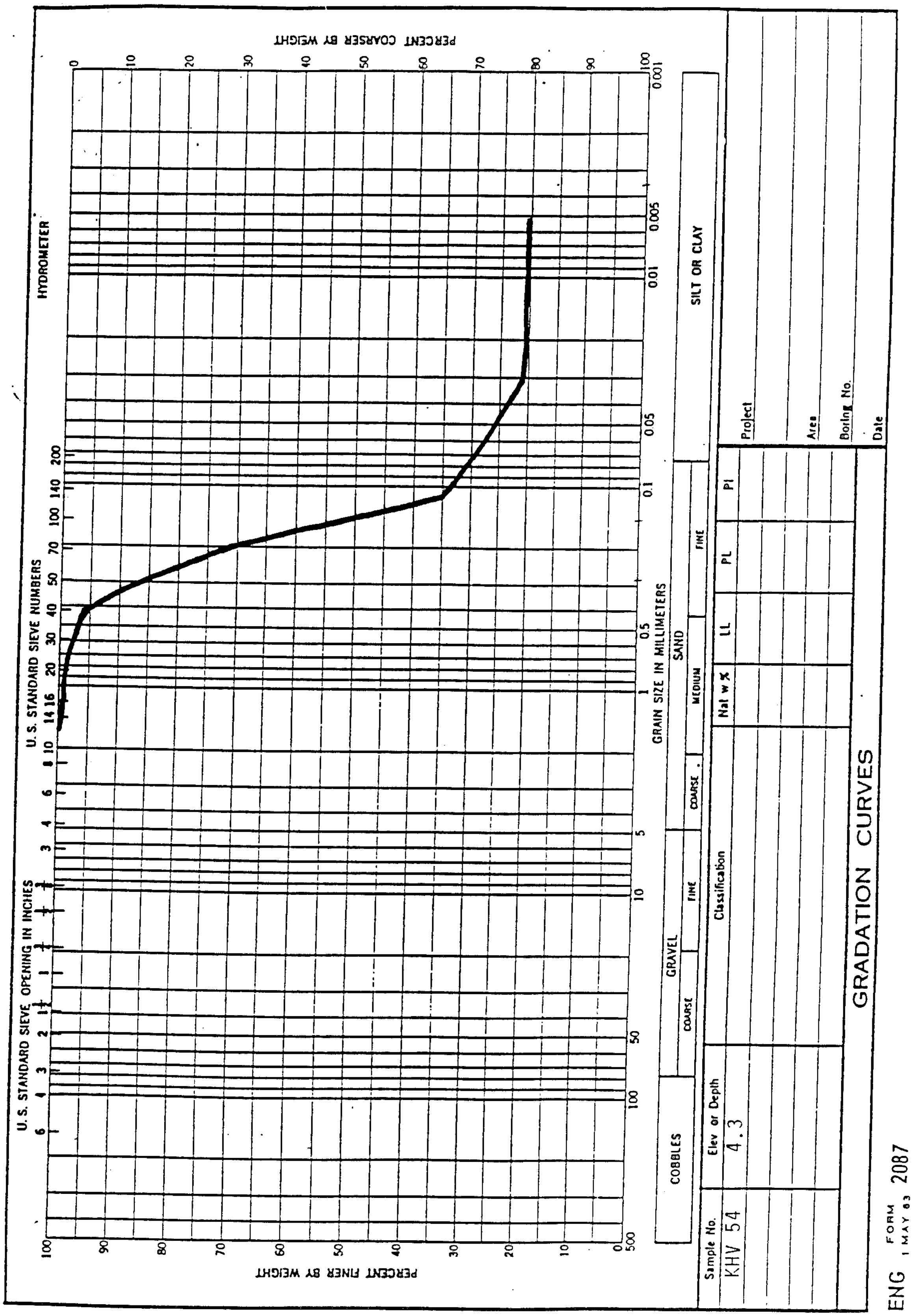
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11	SC	Dark gray, clayey sand			
	12					
	13					
	14	SC	Dark gray, clayey sand			
	15					
	16					
	17	SC	Dark gray, clayey sand			
	18					
	19					
			19.8 ft Recovery			
	20					
	21					

ENG FORM 1836 Project Hole No.


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 54
Elev or Depth
0.4
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 54
Elev or Depth
1.4
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 54
Elev or Depth
4.3
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 778548.00E, 199533.80N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril
4. Hole No. (As shown on drawing title) KHV-55	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started 6/11/93 — Completed 6/11/93
7. Thickness of Overburden	17. Elevation Top of Hole -46.9'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole	19. Signature of Inspector JV GZ

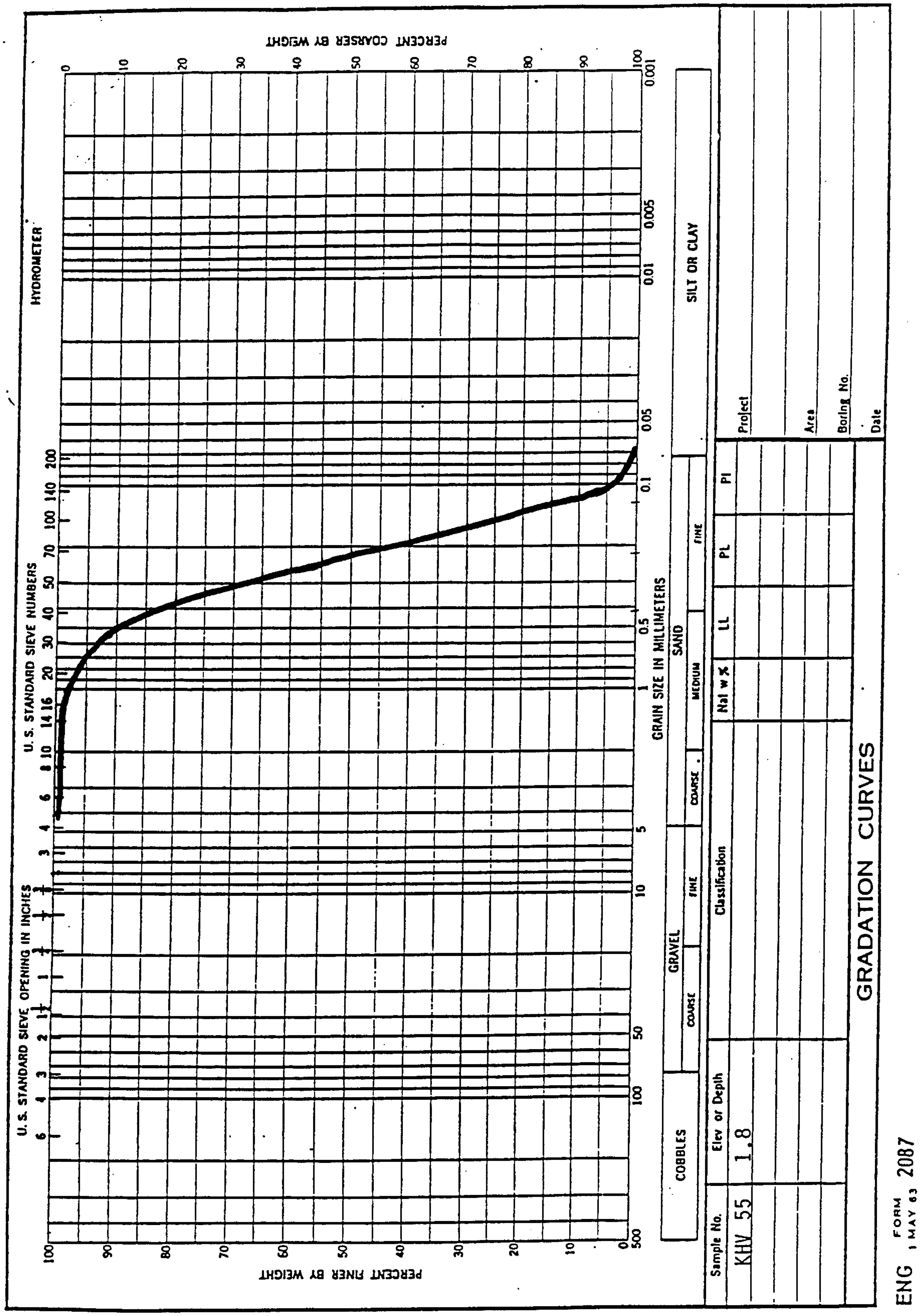
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0–1	CH	Dark gray clay; high plasticity; wet	100		
	1–2	SP	Dark gray, medium to fine sand			Sample at 1.8'
	3		Dark gray, medium sand			
	4–5	SP				Sample at 4.0' Sample at 4.5'
	6			100		
	7		Darker gray, medium sand			
	8	SP				
	9–10	SP	Dark gray, coarse sand			Sample at 9.8'

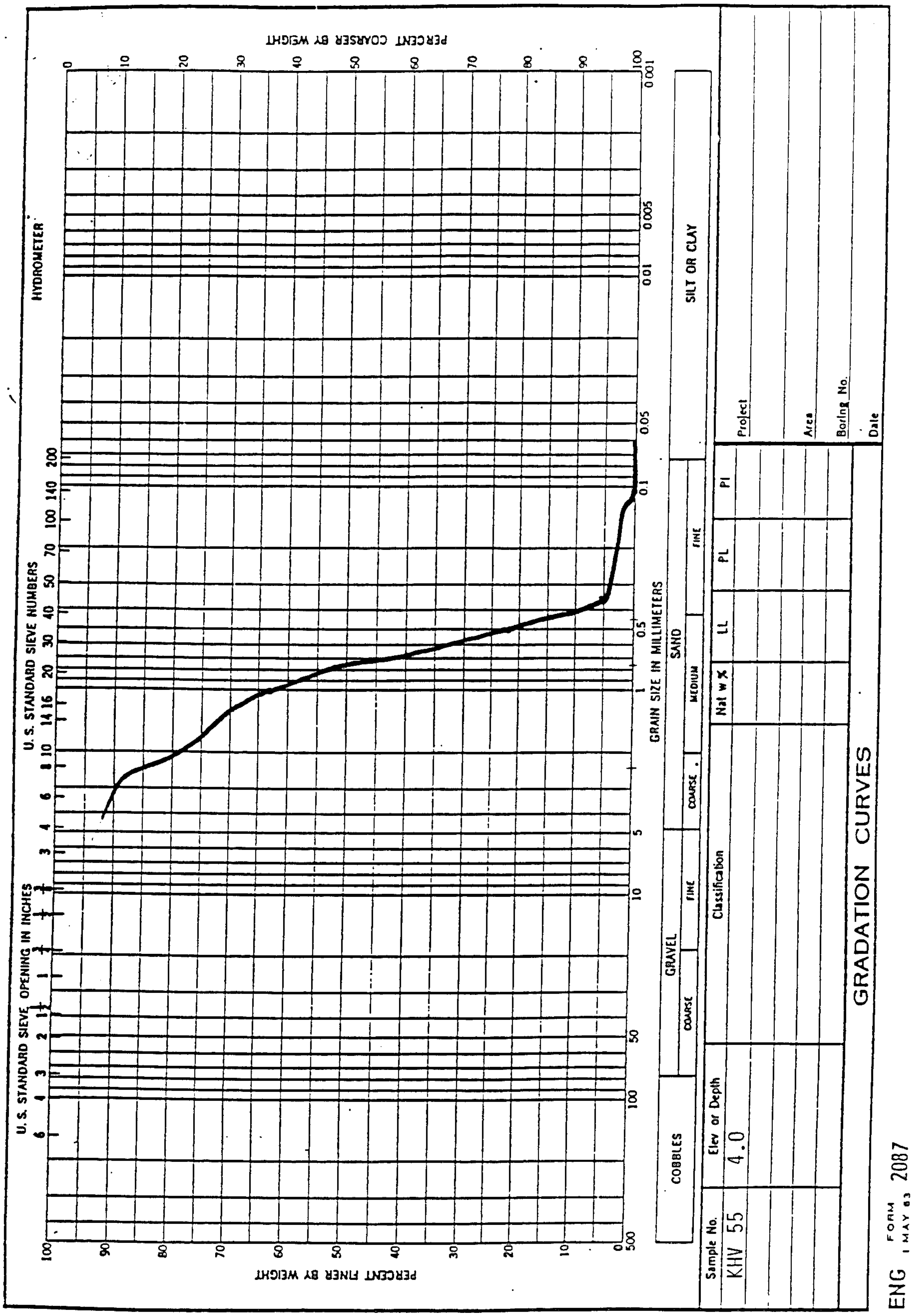
ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -46.9'	Hole No. KHV-55
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10–12.7	SP	Dark gray, medium sand; trace of clay	100		
	12.7–20	CL	Dark gray, clay and silt; low plasticity			
		CL	Dark gray clay; low plasticity	100		
	20		20 ft Recovery			
	21					

NG FORM 1836 Project Hole No.


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 55
Elev or Depth
1.8
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087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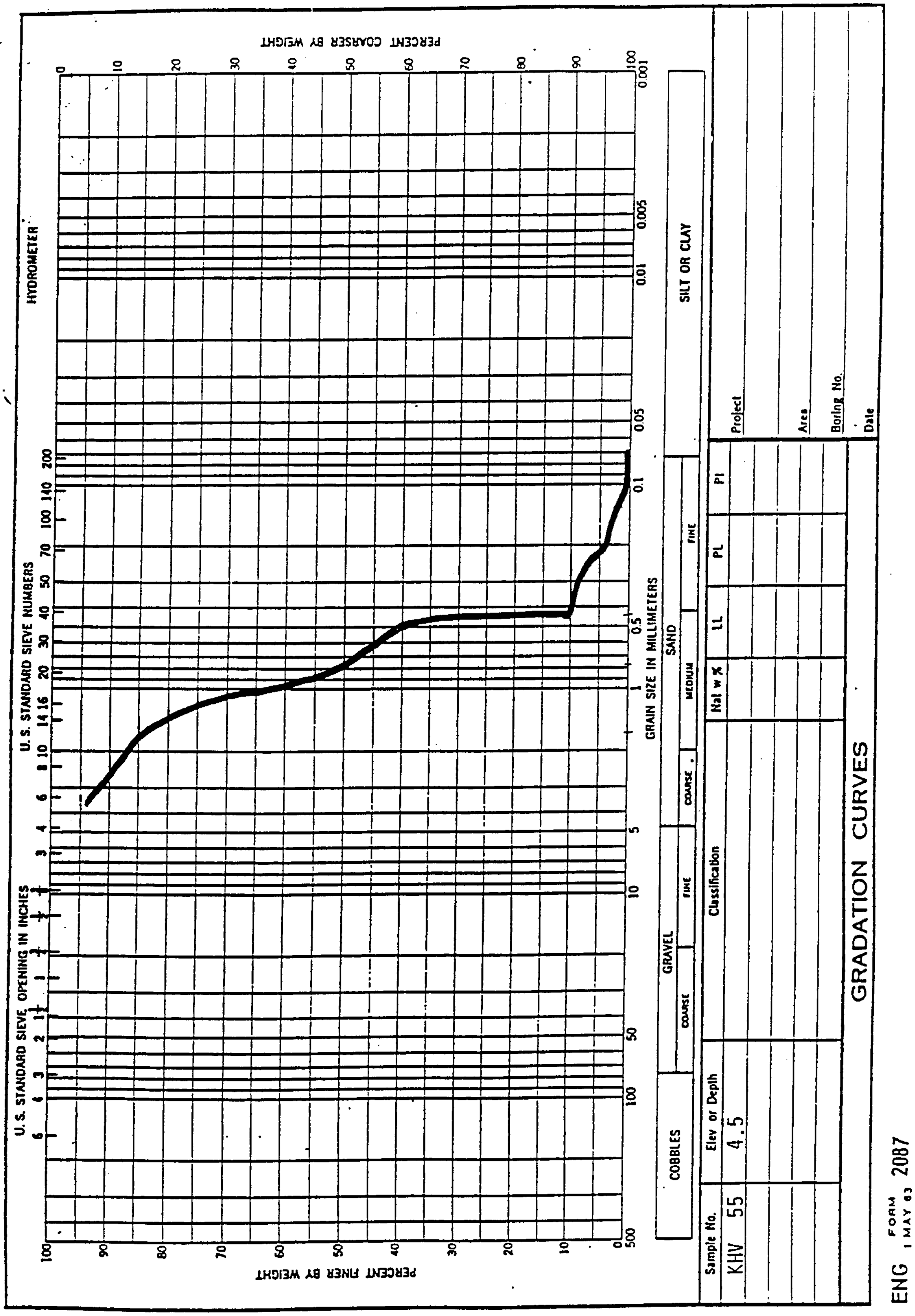
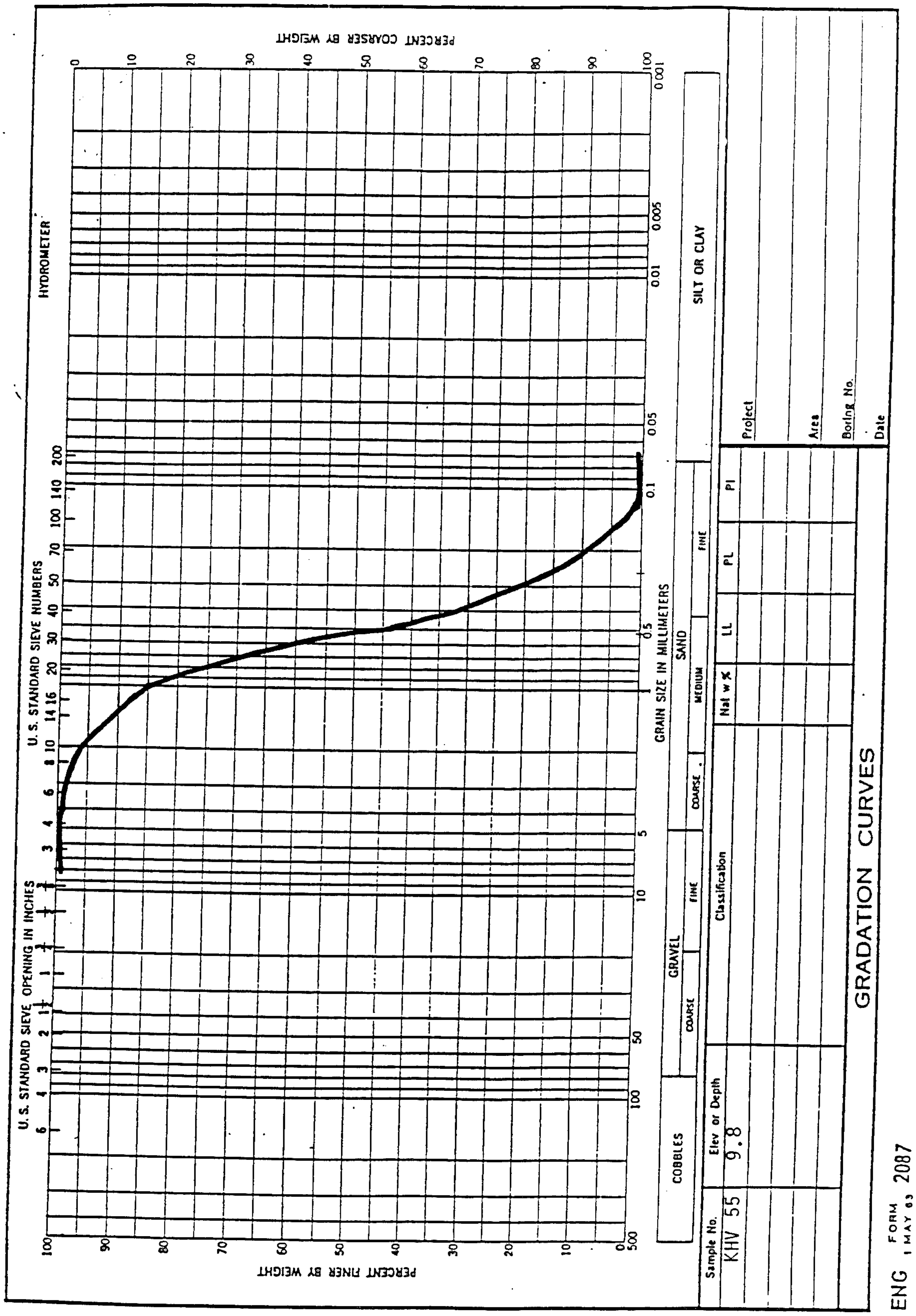
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 55
Elev or Depth
4.0
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



GRADATION CURVES
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 55
Elev or Depth
4.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
ENG FORM 1 MAY 63 2087


U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 55
Elev or Depth
9.8
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log | 1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 760909.40E, 230660.50N	11. Datum for Elevation Shown (TDM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Dril.
4. Hole No. (As shown on drawing title) KHV-56	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started — Completed
7. Thickness of Overburden	17. Elevation Top of Hole -30.9'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole 19.8 ft	19. Signature of Inspector JV GZ

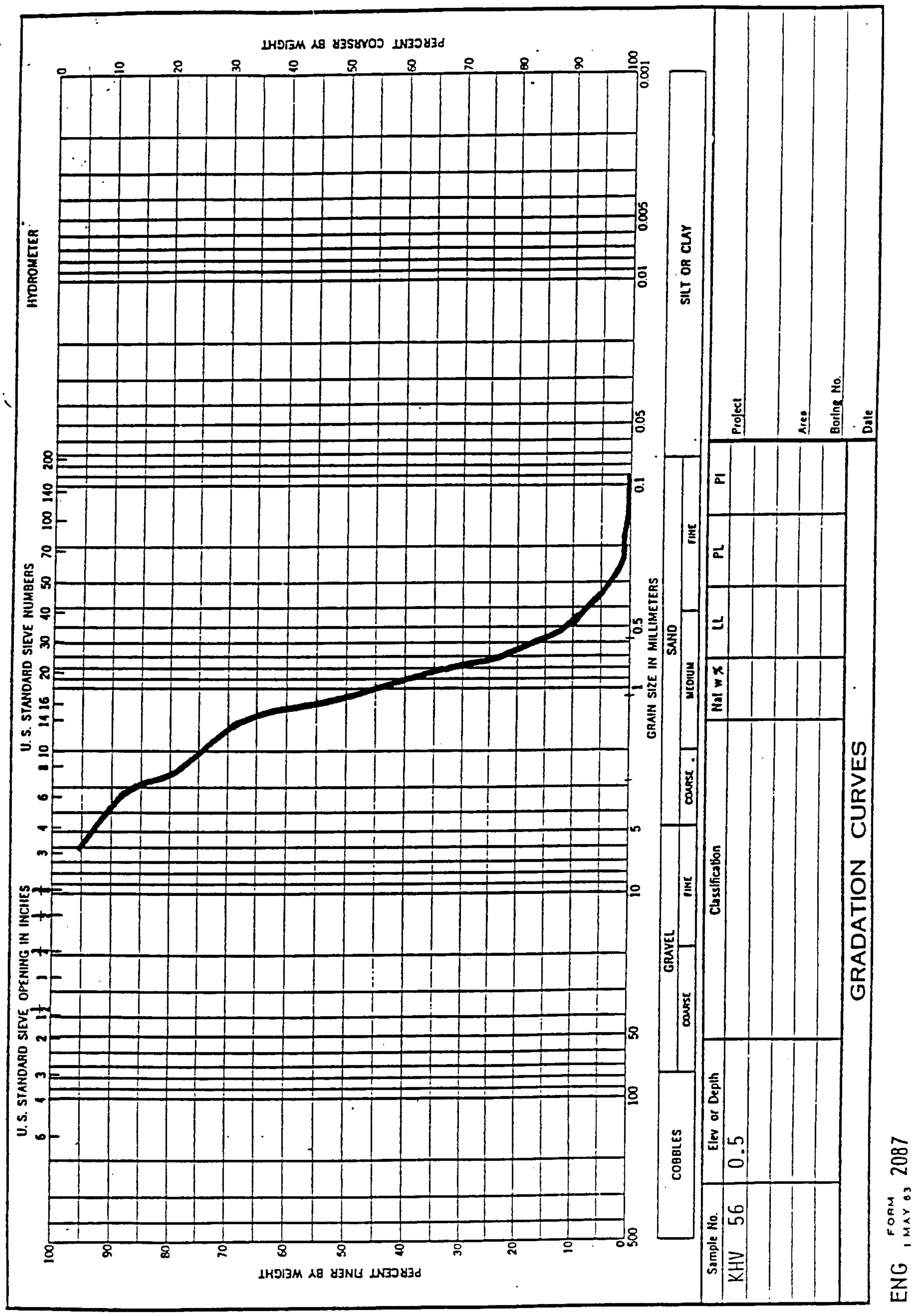
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0	SW	Medium to coarse sand; trace gravel	100		Sample at 0.5'
	1	ML	Dark gray, plastic mud			
	2	SP	Medium to fine sand mixed with dark gray mud			Sample at 3.0'
	3–5	SP	Light gray, medium sand	100		Sample at 5.0'
	6–9	SP	Light gray, medium sand			
	9	SP	Light gray, medium sand	100		
	10	GP	Tan, coarse sand and gravel			Sample at 10.0'

ENG FORM 1836 Project Hole No.

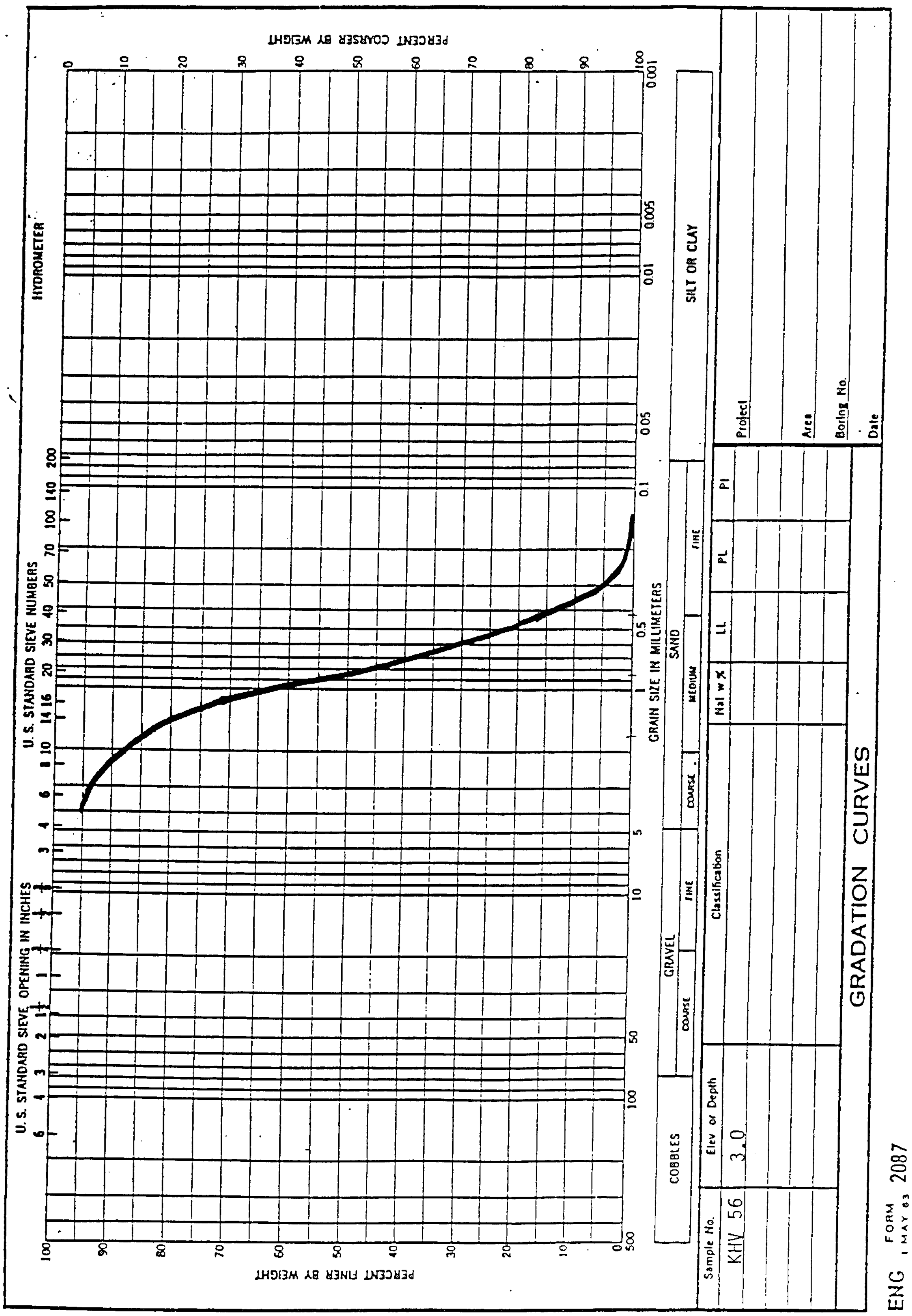
Drilling Log (Cont Sheet)	Elevation Top of Hole -30.9'	Hole No. KHV-56
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	PT	Peat and plant material	100		Gravel and pebble lag deposit below peat layer—"Transgressive Lag"
	11	GM	Pebbles, gravel, sand, mud mixture			
		SC	Medium sand and clay			
	12–13	SC	Medium to dark gray clayey sand			
	14–16	SC	Dark gray clayey sand			Sample at 15.0'
	17–19	SC	Medium gray clayey sand			
			19.8 ft Recovery			
	20					
	21					

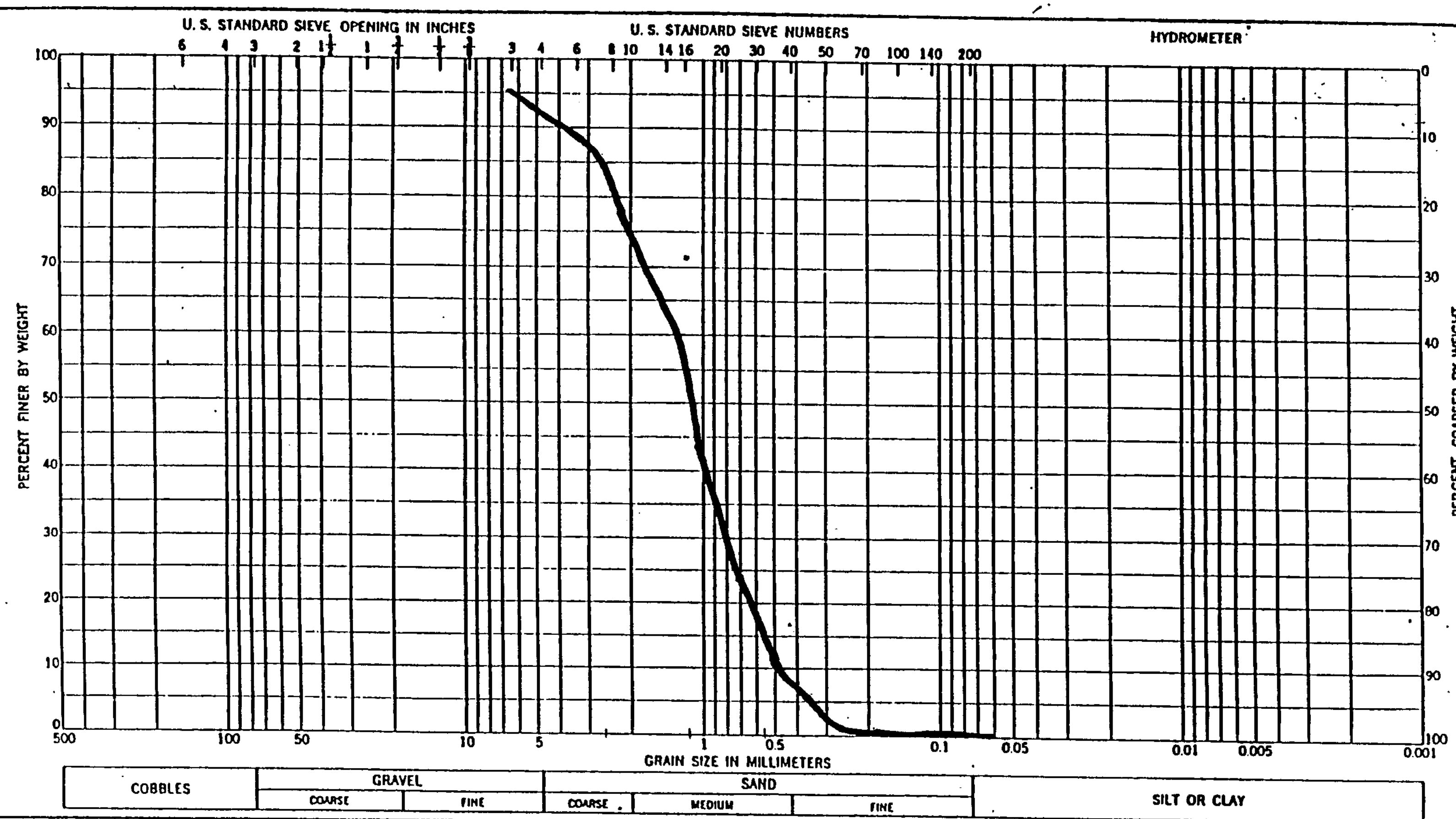
NG FORM 1836 Project Hole No.



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
HYDROMETER
U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 56
Elev or Depth
0.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
KHV 56
3.0
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 2087
1 MAY 63



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
KHV 56	5.0					

Project

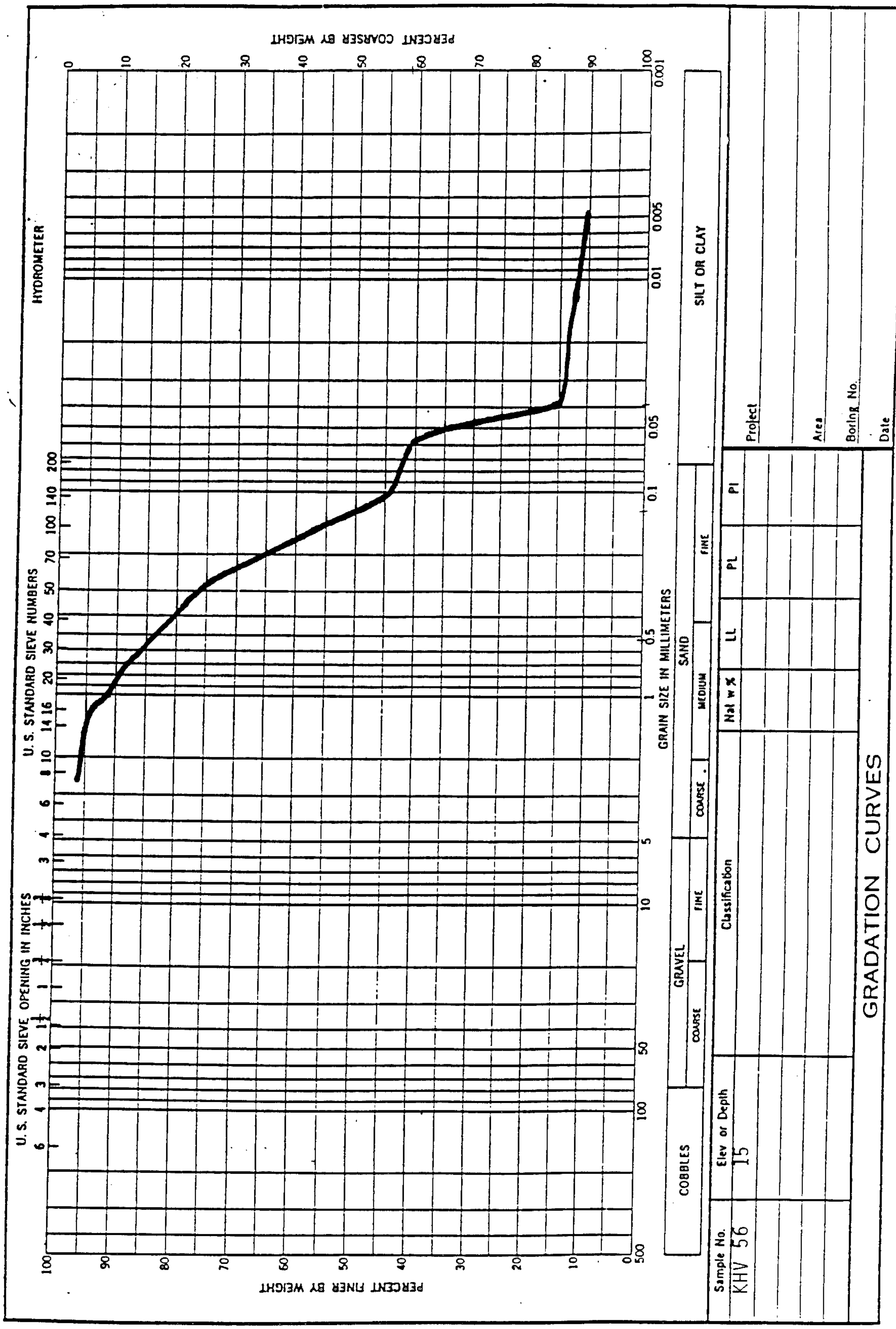
Area

Boring No.

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087



ENG FORM 1 MAY 63 2087

Drilling Log

1. Project KHV	10. Size and Type of Bit
2. Location 770713.80E, 227991.20N	11. Datum for Elevation Shown (TDM or MSL) MLLW
3. Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-57	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
	15. Elevation Ground Water
6. Direction of Hole [x] Vertical [ ] Inclined ____ Degree from Vertical	16. Date Hole — Started 6/10/93 — Completed 6/10/93
	17. Elevation Top of Hole -39.9'
7. Thickness of Overburden	18. Total Core Recovery for Boring %
8. Depth Drilled Into Rock	19. Signature of Inspector JV MC
9. Total Depth of Hole 19.7 ft	

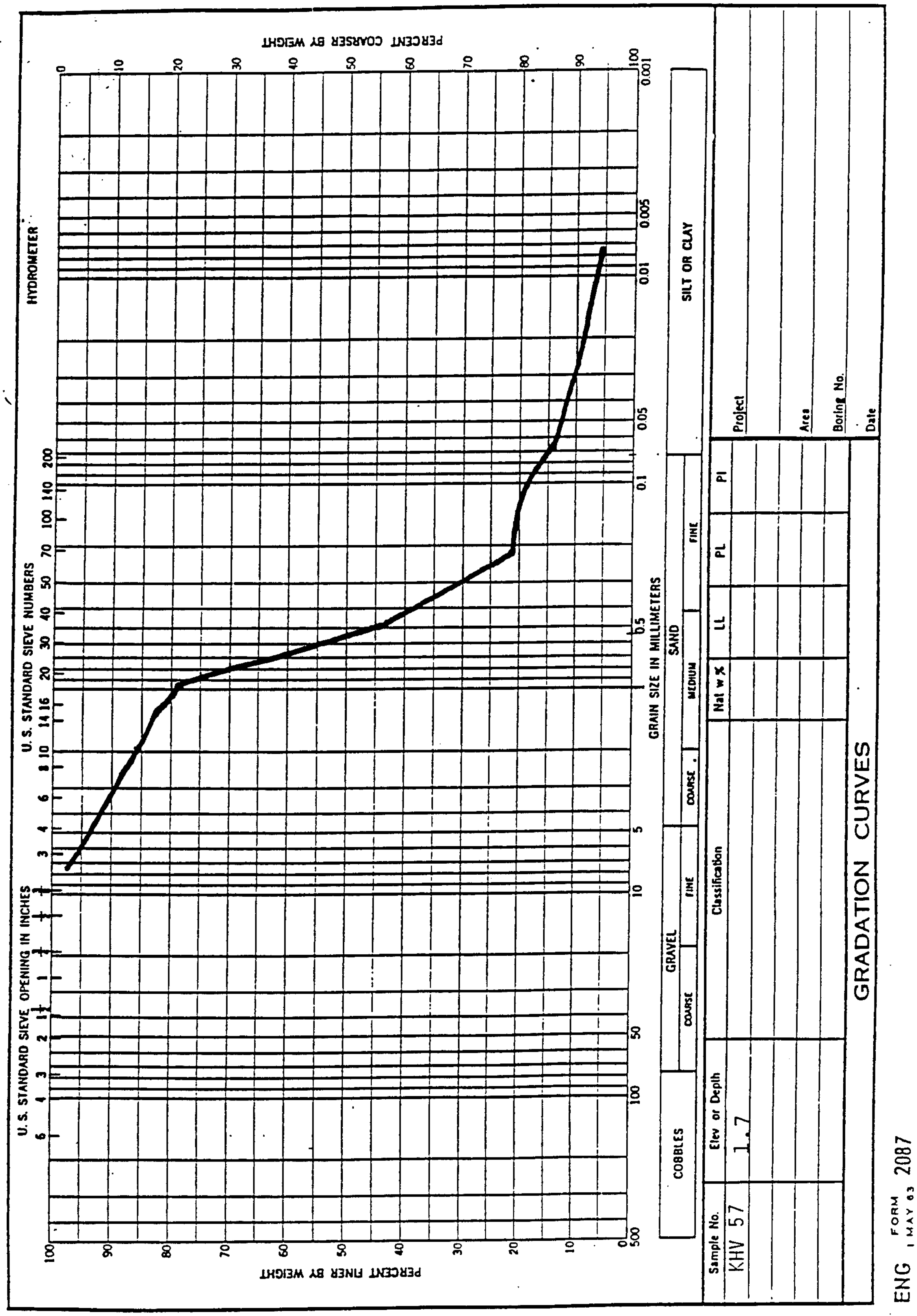
Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	0					
		SC	Dark gray-brown clayey sand			
	1					
						Sample at 1.7'
	2					
	3					
		SC	Dark gray clayey sand			
	4					
	5					
	6					
	7					
		SC	Dark gray clayey sand			
	8					Sample at 7.7'
	9					
	10					

ENG FORM 1836 Project Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -39.9'	Hole No. KHV-57
Project KHV	Installation	Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10					
	11	SC	Dark gray clayey sand			
	12					
	13					
	14	SC	Dark gray–brown clayey sand			
	15					
	16					
	17	SC	Dark gray–brown clayey sand			
	18					Sample at 18.0'
	19		19.7 ft Recovery			
	20					
	21					

NG FORM 1836 Project Hole No.


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 57
Elev or Depth
1.7
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087

Drilling Log

1 of 2 Sheets

1. Project KHV	10. Size and Type of Bit
2. Location 758236.63E, 267199.32N	11. Datum for Elevation Shown (TOM or MSL) MLLW
Drilling Agency Alpine Ocean Seismic Survey, Inc.	12. Manufacturer's Designation of Drill
4. Hole No. (As shown on drawing title) KHV-58	13. Total No. of Overburden Samples Taken — Disturbed — Undisturbed
5. Name of Driller	14. Total No. of Core Boxes
6. Direction of Hole [x] Vertical [ ] Inclined ______ Degree from Vertical	15. Elevation Ground Water
	16. Date Hole — Started — Completed
7. Thickness of Overburden	17. Elevation Top of Hole -39.7'
8. Depth Drilled Into Rock	18. Total Core Recovery for Boring %
9. Total Depth of Hole	19. Signature of Inspector JV

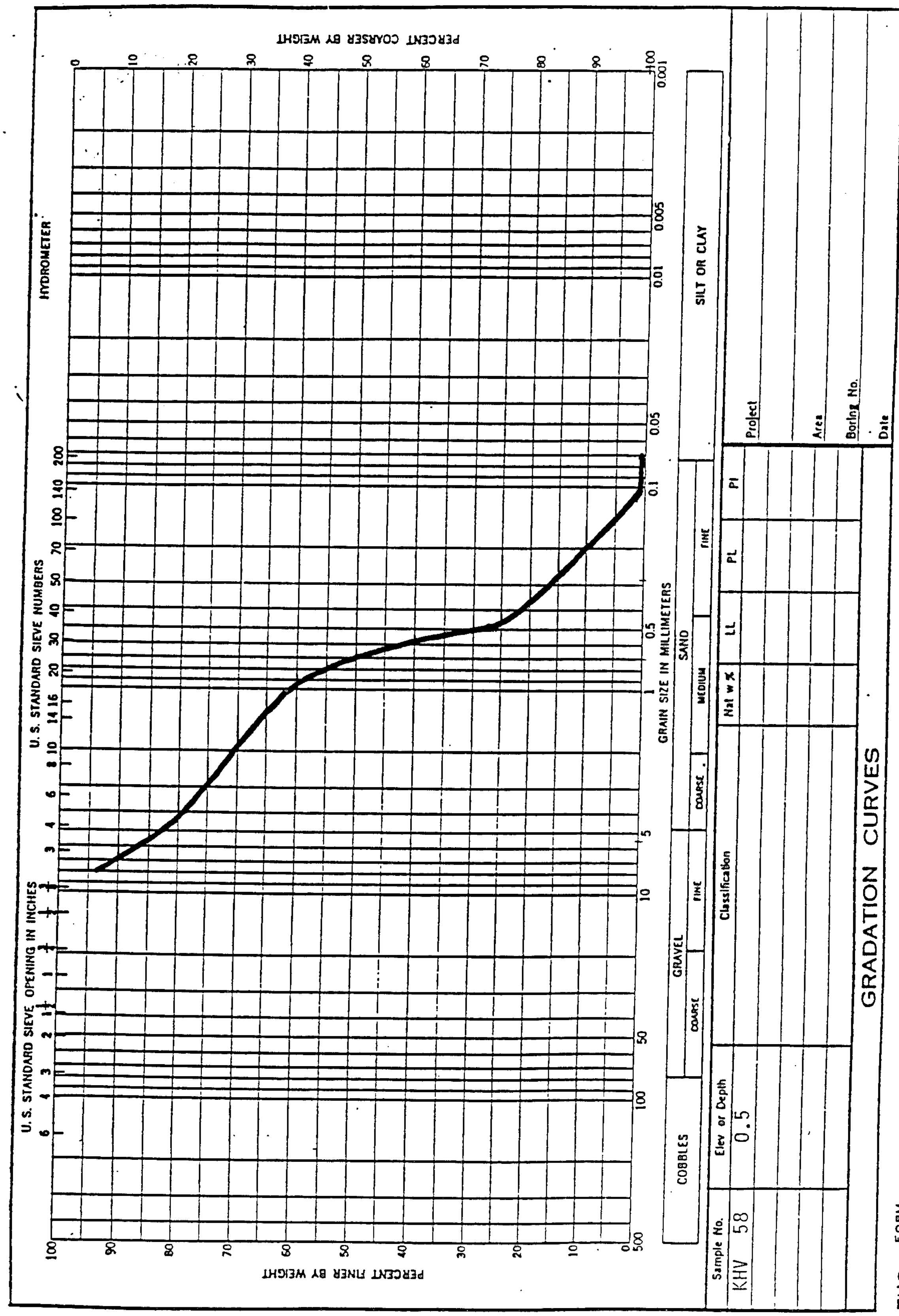
Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, if significant) (g)
	0–1.4	SW	Dark gray, medium sand and gravelGray, medium sand			Sample at 0.5'
	1.4–5.4	SP	Gray-brown, medium sand; some lenses of mud			Sample at 3.0'
		SP	Gray, medium sand			
	5.4–6.1	SC	Gray, medium sand/clay			
	6.1–7.5	SP	Gray silt and medium sand			
	7.5–8.8	SC	Gray, silty clayey sand			Sample at 8.3'
	8.8–10	SP	Gray, medium sand; clean			Sample at 9.6'

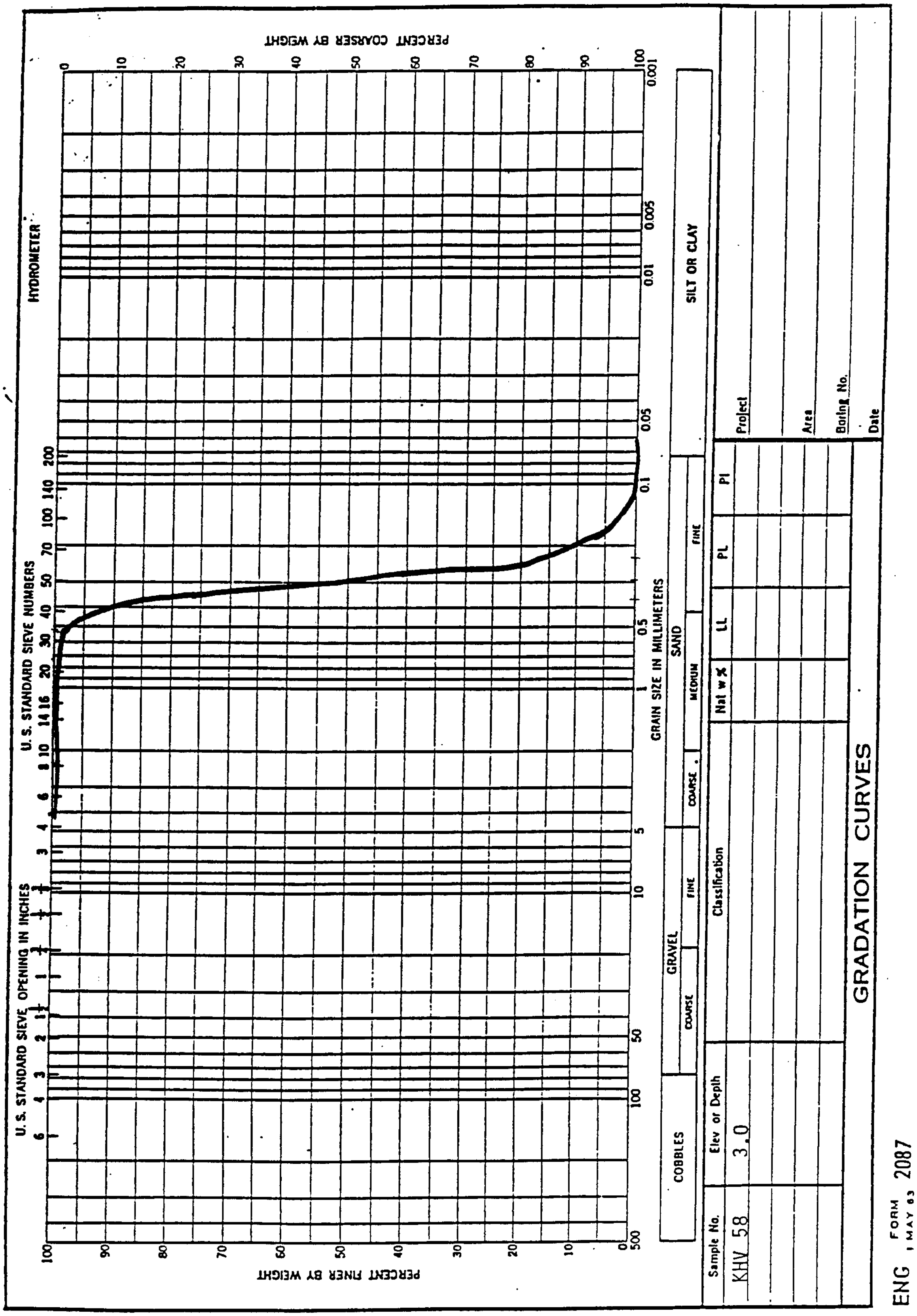
ENG FORM 1836 — Project — Hole No.

Drilling Log (Cont Sheet)	Elevation Top of Hole -39.7'				Hole No. KHV-58
Project KHV		Installation			Sheet 2 of 2 Sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, if significant) g
	10	SP	Gray, medium sand			
	11					
	12					
	13		Slight color change (to tan) at 13'			Sample at 13.0'
	14					
	15	SC	Brown, clayey, medium sand; clay as 2-in. thick plugs			Sample at 15.4'
	16					
	17					
	18					
	19	SP	Clean, brown, medium sand 20 ft Recovery			Sample at 19.5'
	20					
	21					

.G FORM 1836 Project Hole No.


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 58
Elev or Depth
0.5
Classification
Nat w %
LL
PL
PI
Project
Area
Boring No.
Date
GRADATION CURVES
ENG FORM 1 MAY 63 2087



U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 14 16 20 30 40 50 70 100 140 200
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
KHV 58
Elev or Depth
3.0
Classification
Nat w%
LL
PL
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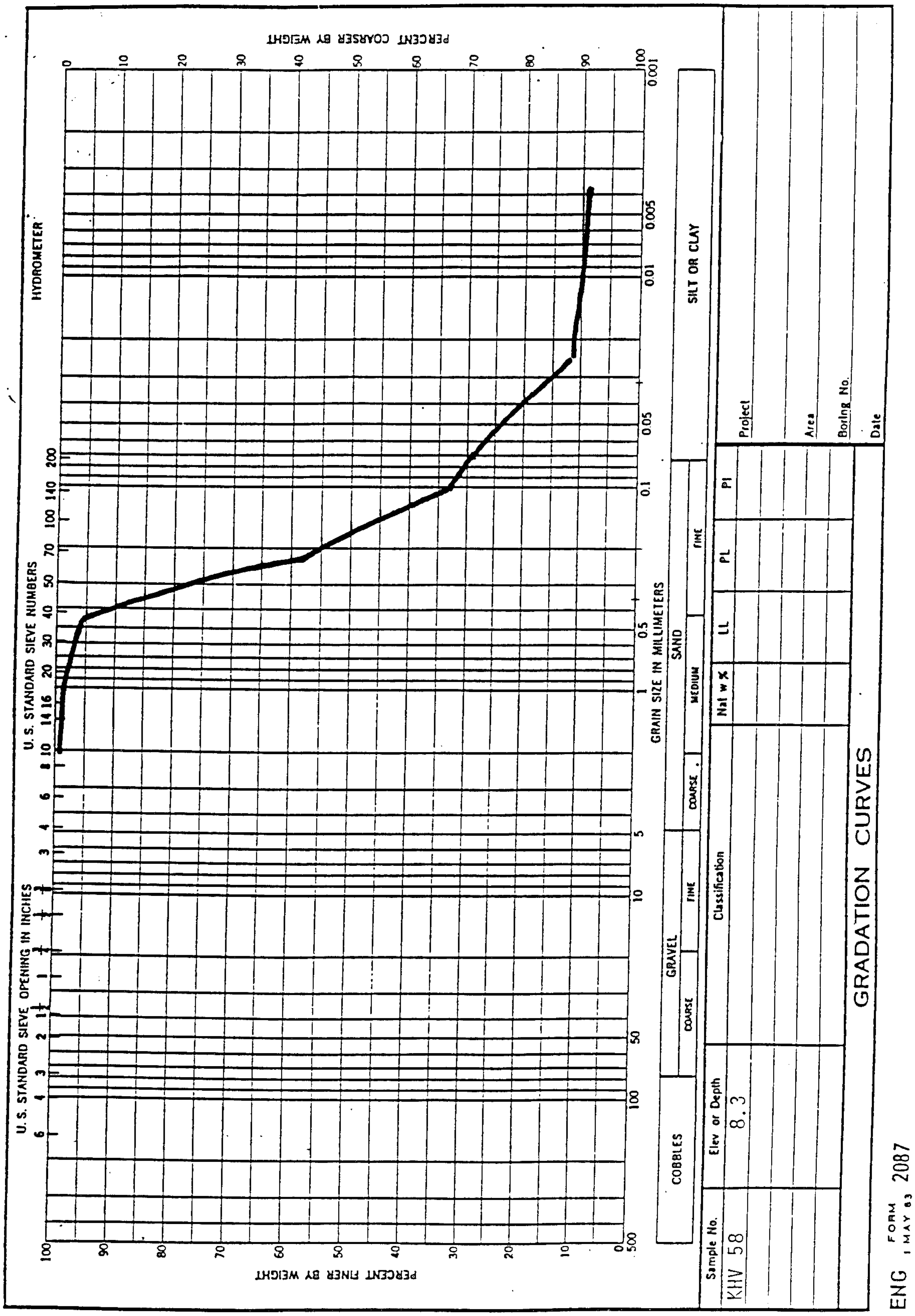
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PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
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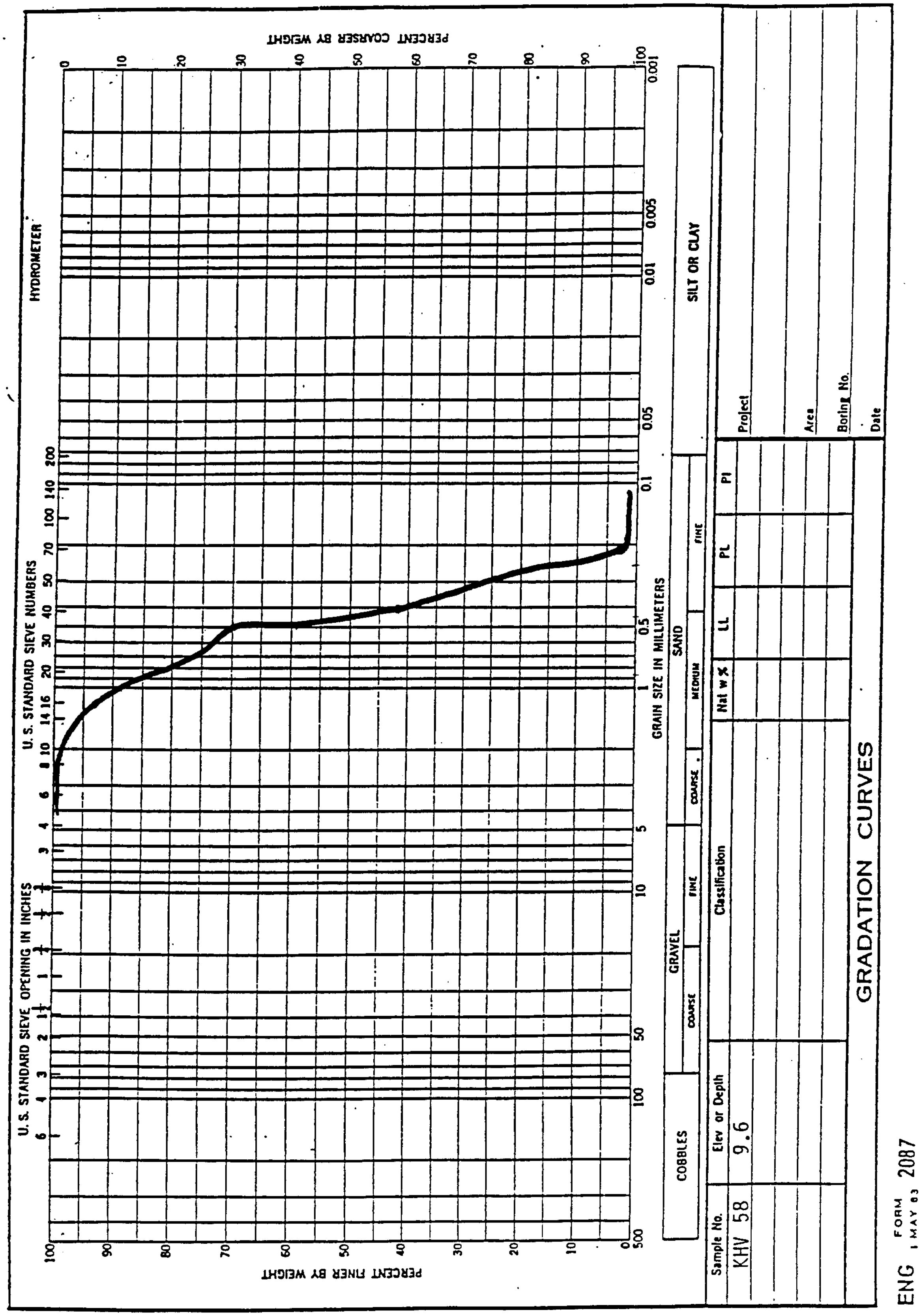

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GRAVEL
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Sample No.
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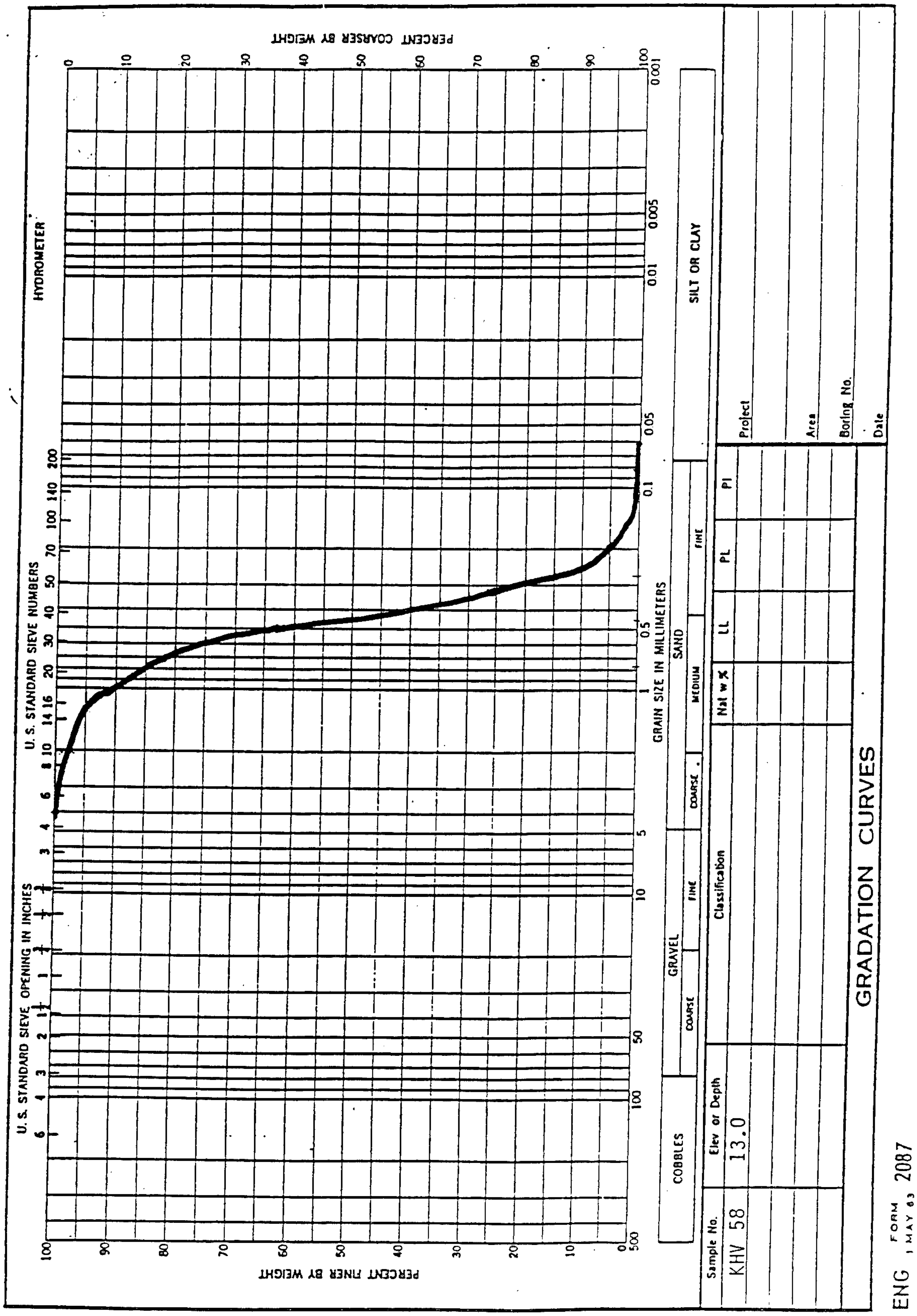
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FINE
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SILT OR CLAY
Sample No.
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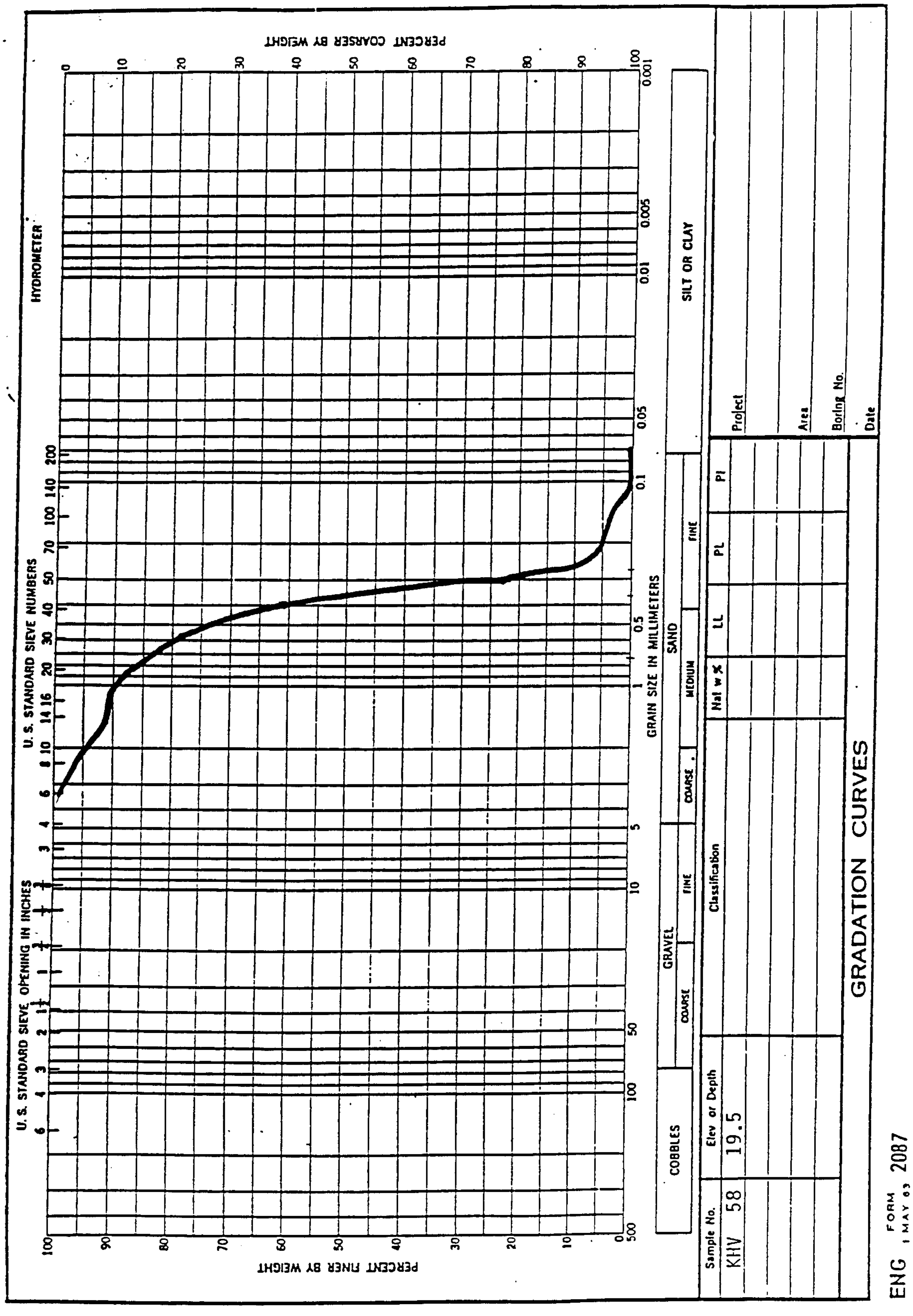
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GRAIN SIZE IN MILLIMETERS
COBBLES
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COARSE
FINE
SAND
COARSE
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FINE
SILT OR CLAY
Sample No.
KHV 58
Elev or Depth
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Classification
Nat w %
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13.ABSTRACT *(Maximum 200 words)*

A comprehensive geoacoustic study has been performed for a 3-mile-wide area offshore of the Delaware coast between Cape Henlopen and Fenwick Island for the purpose of defining the limits of available granular materials. The work was performed in support of the U.S. Army Engineer District, Philadelphia's, feasibility study for shore protection solutions for the Atlantic coast of Delaware. Specifically, the objective of this investigation was to quantify the bottom and subbottom sediments in terms of in situ density, mean grain size, and soil type from the seafloor surface to a depth of about 20 ft below the bottom, where possible, providing initial estimates of the sediment characteristics related to their potential use as beachfill material. A high-resolution acoustic reflection technique was used to quantitatively assess the characteristics of the naturally occurring marine sediments. Analysis of 3,500- and 1,000-Hz seismic reflection data in conjunction with vibracore sampling data from selected sites throughout the Delaware coast study area has been completed. The seismic data were correlated with the laboratory analysis of the sample data through acoustic impedance and acoustic absorption analysis. This being a reconnaissance level study, the results are not intended to assess the suitability of any marine sediment as beach quality material; rather the results are intended to pinpoint areas for further detailed investigations.

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Geophysical methods
Marine sediments

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